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The Scientific English Reader.

ENGLISCHES NATURWISSENSCHAFTLICH-TECHNISCHES LESEBUCH

FÜR HÖHERE TECHNISCHE LEHRANSTALTEN
UND ZUM SELBSTUDIUM FÜR
STUDIRENDE, LEHRER, TECHNIKER, INDUSTRIELLE.

MIT
SPRACHLICHEN UND SACHLICHEN ERLÄUTERUNGEN.

VON

Dr. F. J. WERSHOVEN.

III. TEIL.

BAU-INGENIEURWESEN.

Mit 6 Abbildungen in Holzschnitt.

LEIPZIG:
F. A. BROCKHAUS.
1881.

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VORWORT.

Das vorliegende Werk hat — in Verbindung mit dem unlängst erschienenen *Technical Vocabulary** — den Zweck, Studirende und Lehrer der Naturwissenschaft und Technik, sowie in der Praxis stehende Techniker und Industrielle durch verhältnissmässig geringen Aufwand von Zeit und Mühe mit der neuern naturwissenschaftlich-technischen Sprache und Literatur Englands soweit vertraut zu machen, dass sie im Stande sind, durch das Studium der in der fremden Sprache abgefassten Werke und Zeitschriften die Fortschritte und Leistungen des Auslandes in ihrem Fache zu verfolgen und zu prüfen.

Eine solche naturwissenschaftlich-technische Chrestomathie scheint mir zweckentsprechend zu sein, wenn sie einerseits, ohne bei mässigem Umfang ein wichtiges Gebiet zu übersehen, Aufsätze enthält, welche von hervorragenden Fachmännern nach dem neuesten Standpunkt der Wissenschaft geschrieben sind und bei klarer Darstellung die Kenntniss der wichtigsten Ausdrücke des betreffenden Faches vermitteln, — wenn sie anderseits dem Leser die sprachlichen und sachlichen Schwierigkeiten erläutert und so das beständige zeitraubende und oft doch ver-

* *Technical Vocabulary, English and German.* Für technische Lehranstalten und zum Selbstudium für Studirende, Lehrer, Techniker und Industrielle. Von Dr. F. J. Wershoven. Mit einem Vorwort von Geh. Regierungsrat A. v. Kaven, Director der technischen Hochschule in Aachen (Leipzig, F. A. Brockhaus, 1880).

gebliche Suchen in Wörterbüchern erspart. Ich wünsche, dass mir der schwere Versuch, ein derartiges Hülfsmittel zu schaffen, einigermassen gelungen sein möge.

Die Aufsätze sind hauptsächlich entnommen den Werken von Maxwell, Lockyer, Roscoe, Wilson, Atkinson, Jenkin, Wagner-Crookes, Bloxam, Smiles, Philips, Rankine, Vose, Barry, Shelley, Thurston u. a., ferner den Encyklopädien von Ure, Chambers, Spon *(Dictionary of Engineering)*, Knight *(American Mechanical Dictionary)*, und den Zeitschriften *Engineering*, *The Engineer*, *Iron*, *The Scientific American*, *The Artizan*, *The Journal of Science*, *The Nineteenth Century*, *Proceedings of the Royal Society*.

Dieser dritte Teil ist dem Bau-Ingenieurwesen gewidmet; der zweite Teil behandelt Maschinentechnik und mechanische Technologie; der erste Teil umfasst Physik, Chemie und chemische Technologie. Ein genau entsprechendes französisches Lesebuch, im Anschluss an das *Vocabulaire technique français-allemand* (Leipzig, F. A. Brockhaus, 1879), soll demnächst folgen.

Den Herren Geh. Regierungsrat A. v. Kaven (Aachen), Geh. Regierungsrat Professor Reuleaux (Berlin), Dr. Scheffler (Dresden), H. Gillmann (London), L. Becker (Tiverton), H. Ziegler (New Charlton), R. Land (Dresden) und K. Kommissionsrat F. C. Glaser (Berlin) beehre ich mich auch an dieser Stelle für ihre freundliche Unterstützung ergebensten Dank auszusprechen.

Brieg, im März 1881.

Dr. WERSHOVEN.

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1. ENGINEERING GEODESY.*

Surveying [1], *Levelling* [2], and *Setting-out* [3], comprehend the principal operations of Engineering** Geodesy [4]: the object of surveying and levelling being to make a representation on paper of the ground on which the proposed engineering work is to be executed; and the object of setting-out being, to mark upon the ground the situation of the proposed work preparatory to its execution. The term "surveying", when used in a comprehensive sense, includes levelling; but in a restricted sense, *surveying* is used to denote the art of ascertaining and representing the form of the ground and the relative positions of objects upon it, as projected [5] on a horizontal surface; and *levelling*, to denote the art of ascertaining and representing the relative elevations [6] of different parts of the ground, and of objects upon it.

** *Engineering.* In a comprehensive sense, engineering includes *architecture* as a mechanical art, in distinction from architecture as a fine art; *chemistry* as applied in connection with applied mechanics; *transportation*, including the building and propulsion of ships and other vehicles, docks, roads, bridges, canals, and public works generally; *defense* and *offense*, in the military and naval sense; *water-works; gas-lighting;* the *preparation of materials; machinery; manufacturing;* &c. It is divided into *military* and *civil engineering*, the former being, strictly, the science and art of designing and constructing defensive and offensive works, while *civil engineering* is the science and art of designing and constructing machinery and public works, such as roads and canals. *Civil engineering* refers, according to modern usage, strictly to the construction of *fixed* public works, such as railways, canals, aqueducts, bridges, light-houses, docks, embankments, break-waters, dams, sewers, tunnels, &c. *Mechanical engineering* refers strictly to machinery, such as steam engines, machine tools, mill work, &c. *Engineering* is further divided into steam engineering, hydraulic engineering, gas engineering, agricultural engineering, topographical engineering, &c. WEBSTER.

[1] Aufnehmen. [2] Nivelliren. [3] Abstecken. [4] *geodesy* Geodäsie, gr. γέα, γῆ, Erde, δαίειν teilen. [5] *to project* projiciren, *polar projection* Polarprojection, *stereographic (orthographic) projection* stereographische (orthographische) Projection, *plane of projection* Projectionsebene. [6] Höhe, Höhenlage.

* S. *Technical Vocabulary, English and German* (Technisches Vocabular für höhere technische Lehranstalten und zum Selbstudium. Von Dr. F. J. Wershoven. Mit einem Vorwort von Geh. Regierungsrat A. v. Kaven. Leipzig, F. A. Brockhaus, 1880). ch. 56.

The results of surveying, laid down on paper by the operations of "plotting"[7] and drawing[8], constitute a *plan* or *ground plan*[9]; those of levelling are usually laid down in the form of a *vertical section*, called more briefly a *section*.[10]

A *plan* is a miniature representation[11] of the ground and the objects upon it, and of the proposed engineering work, as projected on a horizontal surface, that surface being represented by the surface of the paper on which the plan is drawn. A plan differs from a map chiefly in the *scale*[12] on which it is drawn. The scale means the proportion which distances, as represented on the plan, bear to the corresponding distances on the ground. Amongst continental European nations it is customary to express that proportion by means of a fraction[13], such as 1-10000th. In Britain, it is customary to refer to two units of length[14], a short unit for the paper, and a long unit for the ground. For example — "six inches to one mile" expresses the scale which, according to the continental system, would be called $\frac{1}{10560}$th. The vertical scale, or scale for heights[15], is almost always much greater than the horizontal scale[16]; the proportion in which it is greater is called the "exaggeration"[17] of the scale. Reducing and enlarging plans is performed by hand or by means of instruments called the "pantograph"[18] and the "eidograph".[18]

A vertical *section* shows the figure of a certain line or track on the natural surface of the ground, and of the proposed work to be executed along that line. A certain straight line on the paper, on which the section is drawn, called the *datum-line*[19], represents a fixed horizontal surface at any convenient height above or depth below some fixed and known point, called the *datum-point*.[20]

SURVEYING. — There are two principal methods followed in surveying, each characterized by the elementary mathematical process which it involves: the *method of distances and offets*[21], used for filling up the details of a survey[22], and the *method of triangles*[23], used chiefly for ascertaining the positions of certain *stations*.[24]

The surveyor, making a general exploration[25] of the ground to be surveyed, will choose a series of stations placed generally on

[7] Auftragen. [8] Zeichnen. [9] Plan, Grundplan, Situationsplan. [10] Profil; *longitudinal section* Längenprofil, *transverse* (oder *cross*) *section* Querprofil, *detailed section* Detailprofil, *working section* Arbeitsprofil. [11] verjüngte Darstellung. [12] *scale* (s. T. I, Nr. 2, 19) Massstab, *enlarged (reduced) scale* vergrösserter (verjüngter) Massstab; *scale* Scala, *thermometric scale* Thermometerscala, *circular scale* Gradring (des Aneroidbarometers), *graduated scale* Gradscala; *scale* Wagschale, *pl. scales* Wage; *iron scales* Eisenhammerschlag; *scale*, auch = *incrustation* Kesselstein (des Dampfkessels). [13] s. Teil I, Nr. 41, 32. [14] Längeneinheit; s. Teil II Appendix "English Units of Weight and Measure". [15] verticaler oder Höhenmassstab. [16] horizontaler oder Längenmassstab. [17] Verzerrung. [18] Pantograph, Storchschnabel, gr. πᾶς, παντός alles, γράφειν schreiben; *eidograph* Eidograph, gr. εἶδος Gestalt; *a tracing-point is made to travel over the outlines of the original drawing* ein Fahrstift wird über die Umrisse der Originalzeichnung geführt, *tracer* Fahrstift, *pencil* Zeichenstift. [19] Horizontlinie. [20] Normalfixpunkt. [21] Methode der Abscissen und Ordinaten. [22] *survey* Aufnahme, *detailed survey* Detailaufnahme. [23] *right-angled triangle* rechtwinkeliges Dreieck, *acute (obtuse) angle* spitzer (stumpfer) Winkel. [24] Station, Richtpunkt, Standort; *principal station* Hauptstation, Hauptrichtpunkt. [25] Erforschung, Recognoscirung *(reconnaissance)* des Terrains.

the highest and most open ground, so that each station may command as extensive a view as possible of the ground to be surveyed and that a pole, or other signal placed at each station, may be distinctly visible from the neighbouring stations. These stations should also be chosen so that the imaginary lines[26] connecting them with each other and with a series of conspicuous objects in their neighbourhood, may cover the district to be surveyed with a network[27] of large triangles, two angles at least of each triangle being accessible stations. Triangles in which the angle at the point to be determined is less than 30°, or more than 150°, are said to be "ill-conditioned"[28], and are avoided by skilful surveyors. The accuracy of the measurements in every important triangle should be checked[29] by measuring a "tie-line", from one of its angles to a known point in the opposite side. The principal stations are to be marked permanently by stakes[30], and temporarily, when required, by poles[31] and flags.[32]

The survey of the network of great triangles might be made by measuring one base line only, and finding the lengths of all the other sides of triangles by calculation from their angles, as is done in a great trigonometrical survey. But for the purposes of the long narrow surveys required for engineering projects, it is more convenient to measure each of the principal station lines by the chain. The relative directions of the base lines are determined by measuring the angles they make with each other and with distant objects. This combination of linear and angular measurement[33] is called *traversing.*—The surveyor will choose a set of secondary stations, some in the course of the principal station lines, others at convenient lateral points; the whole so situated that the lines connecting them, which form a networt of smaller or *secondary* triangles[34], may lie sufficiently near to the fences, streams, buildings, and other objects of detail, to enable these to be surveyed from them by the method of distances and offsets.[21]

For measuring with extraordinary accuracy the bases of national trigonometrical surveys, rods of glass and of metal have been used, a correction[35] for expansion by heat being made either by calculation or by mechanism. In ordinary surveys for engineering works so great a degree of accuracy is unnecessary; and the instrument generally used for measuring distances is the common *surveying chain*[36], which consists of 100 straight links of iron or steel wire of equal length, having eyes on their ends, and connected together by oval rings. Each distance of ten links is marked by a peculiarly shaped piece of brass; at each end of the chain is a handle.

[26] *base line, principal station line* Basislinie, Hauptrichtungslinie. [27] Netz. [28] ungünstig. [29] controlliren, prüfen. [30] Pflock. [31] Stange. [32] Fähnchen. [33] Winkelmessung. [34] Dreiecke zweiter Ordnung. [35] Correction. [36] Messkette; *standard chain* Normalkette, *link* Glied, *handle* Handhabe, *arrow* Zählstift; *chain-length* Kettenlänge, *to chain* mit der Kette messen; *tape* Messschnur, *offset-staff* Messstab *(ten links long).*

The chain most commonly used in Britain is "Gunter's chain" of 66 feet or 22 yards (in which each link is ·66 of a foot or 7·92 inches). The advantages of Gunter's chain are, its being an exact decimal fraction of a mile (one-eightieth, or ·0125), and the square described upon it being one-tenth of an acre.[37] The chain is usually accompanied by ten skewers called "arrows", made of iron or steel wire, having a point at one end and a large ring at the other, marked with a piece of red cloth to make it visible from a distance. The chain is carried by two men, called respectively the "leader"[38] and the "follower".

In chaining up or down a slope[40], the distance actually measured must be reduced on the plan to the projection of that distance on a horizontal plane—(reduction to the level[39]). The most convenient way of effecting this is by means of a correction[35] in links and fractions of a link to be deducted from each chain. When the angle of inclination[41] has been measured by a "clinometer"[42] or other angulur instrument; correction in links per chain = 100 × versed sine of inclination.

To save calculation, most clinometers and theodolites have the correction for declivity marked on the "limb". Its use may often be dispensed with by stretching the chain in a horizontal position; the up-hill end touching the ground, and the point on the ground exactly below the down-hill end being found by means of a plumb-line[43], or a ranging pole held vertically, or by dropping a stone. This process is called *stepping*.[44]

SURVEYING INSTRUMENTS.—The *Theodolite*[45] is an instrument whose chief use is to measure angles in a horizontal plane, or "*azimuths*"[46], and which is occasionally used to measure also vertical angles, or *altitudes*[47] and *depressions*.[48] The structure of theodolites varies very much; but there are certain essential parts which are common to all and which will now be enumerated.—The *telescope*[49] consists of two tubes[50], one sliding within the other. The outer tube has, at its further end, the object-glass[51], which forms at its focus[52] an inverted image[53] of the object looked at. The inner tube has, at its nearer end, a combination of glasses, called the "eye-piece"[54], which magnifies[55] that inverted image. By

[37] *Long Measure:*—12 lines = 1 inch; 12 inches = 1 foot; 3 feet = 1 yard (= 0,914 m); 5½ yards = 1 pole, rod, or perch; 40 poles = 1 furlong; 8 furlongs = 1 mile (= 1760 yards = 5280 feet = 1609,3 m); 3 miles = 1 league. 1 chain = 100 links = 22 yards = 4 poles. 1 nautical mile = 1 knot = 6086·5 feet = 1855 mètres. 1 fathom = 6 feet. 1 cable length = 120 fathoms.—*Measure of Area:*—9 square feet = 1 square yard; $30\frac{1}{4}$ square yards = 1 square pole, rod, or perch; 16 square poles = 1 square chain; 40 square rods = 1 rood; 4 roods = 1 statute acre = 10 square chains = 4840 square yards = 0·404 hectare; 640 acres = 1 square mile. Näheres s. Teil II Appendix. [38] *chain-carrier* Kettenträger, *leader* Vordermann, Führer, *follower* Hintermann. [39] Reduction auf die Horizontale. [40] Abhang, Böschung. [41] Neigungswinkel. [42] Bergwage, Klinometer. [43] Bleischnur, Senkel. [44] Staffeln. [45] Theodolit; *surveying instrument* Feldmessinstrument, *transit instrument* Passageninstrument. [46] Azimuth(winkel). [47] Höhenwinkel, Elevationswinkel. [48] Tiefenwinkel, Depressionswinkel. [49] Fernrohr, s. T. I, Nr. 9, *Technical Vocabulary*, ch. 21. [50] Rohr. [51] Objectiv. [52] Brennpunkt. [53] umgekehrtes Bild. [54] Ocular. [55] vergrössern.

moving the inner tube inwards and outwards by a rack and pinion [56], turned by a milled head [57], the foci of the object-glass and eye-piece are adjusted till they coincide, which is known by the steady and distinct appearance of the image. At the common focus there is a "diaphragm" [58], with a round hole in the middle crossed by

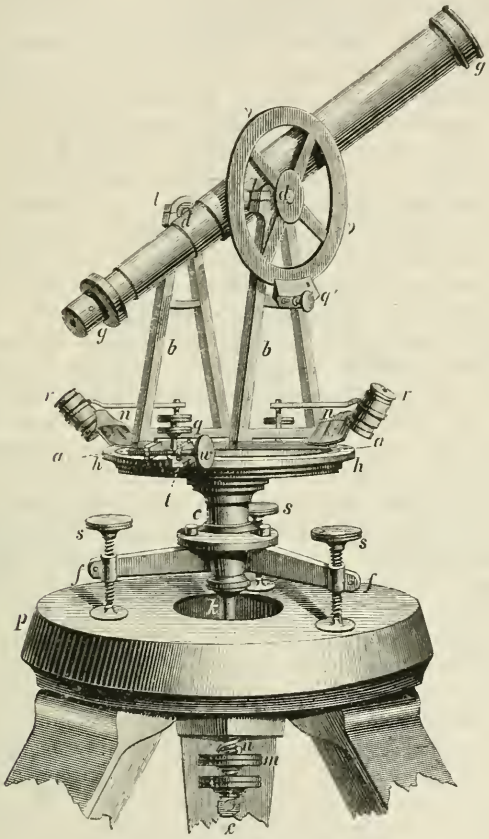

Fig. 1. Theodolite.

spider's lines or equally fine platinum wires, called the cross-wires. [59] The point where those wires cross each other should be exactly in the axis or "line of collimation" [60] of the telescope.—A *spirit-level* [61] is attached to the outer telescope-tube by screws, by means of which it can be set exactly parallel to the line of collimation.—The *hori-*

[56] Zahnstange und Getriebe. s. T. II, Nr. 6. [57] gerändelter Knopf. [58] Diaphragma. [59] Fadenkreuz. [60] Collimationslinie. [61] Libelle, s. 98.

zontal axis, when the instrument is in adjustment, is exactly at right angles to the line of collimation, and exactly level; so that the telescope may turn about on the bearings[62] of that axis in a truly vertical plane.—The *frames* or *supports*[63] of the horizontal axis are high enough, in the transit theodolite[64], to admit of the telescope being turned completely over in a vertical plane. In Colonel Everest's theodolite the supports are made low, for the sake of compactness; but the telescope may be turned completely over by lifting the horizontal axis out of its bearings. In the common theodolite the telescope is not fixed in the middle of that axis, but is supported in two forked rests called Y's[65]; when not required to be lifted out, the telescope is clasped firmly in its Y's by two semicircular arcs called clips.—The *vertical circle* or *altitude circle*[66] is fixed on the horizontal axis; it is divided into four quadrants, the degrees in each of which are numbered from 0° to 90°. There are two indices[67] with verniers[68], at opposite ends of a horizontal bar, read by microscopes; when the line of collimation is horizontal, each of those indices ought to read 0°. In directing the telescope to any object, it is turned at first by hand as nearly in the required direction as possible; then the vertical circle is "clamped"[69] by turning a *clamp-screw*[70] which lays hold of its lower edge; and then, by a *tangent-screw*[71], a slow motion is given to the circle and telescope until the line of collimation points exactly towards the object. In the common theodolite, instead of a vertical circle, there is a semicircle only.—The *vernier-plate*[72] is a circular plate, fixed on the top of, and exactly perpendicular to, the *inner vertical axis*. It carries at its sides the supports of the horizontal axis, in its centre a *magnetic compass*[73] with a glass top, and near its edge a pair of spirit-levels. At two points on its edge, diametrically opposite to each other, are two indices with verniers, read by means of microscopes.—The *horizontal circle*[74] has its edge or *limb*[75] bevelled[76] to the figure of the frustrum of a cone[77], and graduated. The faces of the vernier-plate are portions of the same conical surface. An arm projecting from the vernier-plate carries a *clamp*[78] for laying hold of the circle, and a tangent-screw for giving the vernier-plate a slow-motion.—The *outer vertical axis*[79] is fixed to the horizontal circle, and is a tube, containing within it and accurately fitting the inner vertical axis. It turns round on a ball-and-socket joint[80] at its lower end; and is clamped in any required position by means of a collar with a tightening-screw. From the collar projects an arm, acted upon by means of a tangent-screw. The fixed nut of this screw is attached to the

[62] Lager, s. T. I, Nr. 4, 8. [63] Träger. [64] Compensationstheodolit. [65] Rohrlager. [66] Vertikal- oder Höhenkreis. [67] Zeiger, s. T. I, Nr. 1, 2. [68] Nonius. [69] festklemmen. [70] Klemmschraube. [71] Mikrometerschraube. [72] Alhidade. [73] Bussole, s. T. I, Nr. 10. [74] Horizontalkreis. [75] Limbus. [76] oder *chamfered* abgeschrägt. [77] abgestumpfter Kegel. [78] Klammer. [79] äussere Vertikalaxe, Mantel. [80] Kugelgelenk.

upper parallel plate[81]; four *plate-screws*[82] serve to place the vertical axes truly vertical. The *lower parallel plate* is screwed upon the *staff-head*[83], which is supported by three wooden legs. In the middle of the lower side of the staff-head is screwed a hook, from which a plummet[43] is hung, in order to ascertain whether the centre of the theodolite is exactly over the station on the ground. Instead of the upper parallel plate, Colonel Everest's theodolite has three diverging arms, as in an astronomical circle, with a vertical foot-screw supporting the end of each.

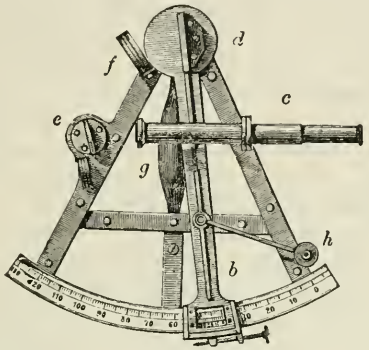

Fig. 2. Sextant.

Reflecting instruments[84] are used chiefly in navigation and marine surveying, but occasionally in land surveying also. The principle upon which they act is this: — that if there are two plane mirrors[85] whose reflecting surfaces make a given angle with each other, and a ray of light, in a plane perpendicular to the planes of both mirrors, is reflected[86] from both successively, its direction after the second reflection makes with its original direction an angle which is double of the angle made by the mirrors with each other. The *Sextant* (Fig. 2) is of the form of a sector of a circle. The degrees on the graduated limb are of one-half of the extent of those on a non-reflecting instrument. The index *(b)* has a vernier and a microscope *(h)* for reading the divisions. The two mirrors have their planes at right angles to the plane of the instrument; one of them, called the "*index-glass*"[87] *(d)*, is carried by the index at its centre of motion; the other, called the "*horizon-glass*"[88] *(e)*, is carried by the frame of the sector; half of it is silvered[89] and the remainder unsilvered. A telescope *(c)* is fixed opposite to the horizon-glass; darkening glasses are used to moderate the light of very bright objects. To measure

[81] obere Fussplatte. [82] Fussschraube. [83] Stativkopf. [84] Spiegelinstrument. [85] ebene Spiegel, s. T. I, Nr. 9. [86] zurückwerfen, reflectiren. [87] Zeigerspiegel, grosser Spiegel. [88] Kimmspiegel, kleiner Spiegel. [89] versilbert; *darkening glass* Blendglas.

a horizontal or nearly horizontal angle with the sextant, hold the instrument so that the plane of its face shall pass through the two objects subtending the angle: look through the telescope or sight-hole at the object which is farthest to the left, so as to see it through the unsilvered part of the horizon-glass; move the index by hand until the reflected image of the right-hand object is seen in the silvered part of the horizon-glass; clamp the index, and move it slowly by the tangent-screw till that image apparently coincides with the left-hand object. Then read the angle by means of the index and vernier, and add or subtract the index-error[90] according as it lies behind or in advance of 0°.—The *box-sextant*[91] is a sextant so small as to be entirely contained within a cylindrical brass box of about three inches in diameter and two inches in depth; it is graduated to half-degrees.[92]

The *plane-table*[93] is a drawing-board[94], having a sheet of paper strained[95] on it, mounted on a portable three-legged stand, and capable of turning about a vertical axis, and of being adjusted by screws to a horizontal position. The "index" is a flat straight-edged ruler, having upright rights at its ends.

LEVELLING.—The *water-level*[96] consists of an inverted siphon tube[97], fixed on the top of a stand, and nearly filled with water, which may be slightly tinged to make it the more easily visible. The horizontal part of the tube may be of metal; the two vertical branches are of glass. The surfaces of the water stand at the same level in those two branches, and the leveller obtains a horizontal line of sight by looking along a line joining those two surfaces, which may be considered as the line of collimation of the instrument. The water-level is often used, where long range and great accuracy are unnecessary, being more expeditious than the telescopic levelling instrument.

The *spirit-level*[98] strictly speaking is a glass tube hermetically sealed[99] at both ends, containing some very limpid liquid, such as alcohol, chloroform, or sulphuret of carbon[100], and a bubble of air, and having a slight curvature[101], convex upwards. The glass tube is usually fixed in and protected by a brass case.[102] The air-bubble[103] places itself at the highest point in the tube. When the bubble is not in the middle of the tube, it indicates that a tangent to the middle of the tube deviates from a horizontal position through an angle whose value in seconds is $206264''{\cdot}8 \times \frac{\text{deviation of bubble}}{\text{radius of curvature of tube}}$;

[90] Indexfehler; *arc of excess* Ueberteilung. [91] Dosensextant. [92] *optical square* Winkelspiegel, *cross-staff* Kreuzscheibe, *reflecting circle* Spiegelkreis, *repetition circle* Repetitionskreis, *prismatic compass* Prismacompass, Schmalkalder'sche Bussole, *boning-rod* Visirkreuz, *circumferenter* Grubencompass; *protractor* Transporteur. [93] Messtisch. [94] Reissbret. [95] aufziehen. [96] Wasserwage. [97] Heberrohr. [98] Röhrenlibelle. [99] luftdicht verschlossen. [100] Schwefelkohlenstoff. [101] *radius of curvature* Krümmungshalbmesser. [102] Gehäuse. [103] Luftblase.

so that the longer that radius, the more delicate is the spirit-level.

The term spirit-level or *level*, is also applied to a *levelling instrument*[104], of which the spirit-level proper is the essential part. Various forms of level are used for engineering purposes: the Dumpy level, Troughton's level, the Y-level, &c.

The *levelling-staff*[105] is a rectangular wooden rod, on the face of which is painted in a bold conspicuous manner, a scale[12] of feet, divided into tenths and hundredths, commencing at the lower end of the staff. The staff, when in use, is held exactly vertical; for which purpose it sometimes has a plummet enclosed in a groove at one side of it, and visible through a small piece of glass: it rests on its lower end, which is shot with brass. When the telescope of the level is directed towards the staff, and the line of collimation is truly horizontal, the number of feet and decimals of a foot at which the horizontal cross wire crosses the inverted image of the scale on the face of the staff (subject to corrections to be afterwards explained), shows the vertical depth of the point on which the lower end of the staff stands below the line of collimation. If two such observations are made with the staff at different points, and the level at the same station, the difference between the two readings[106] shows how much the point at which the less reading is taken is higher than the point where the greater reading is taken. In an old form of levelling-staff, now seldom used, a "sliding-vane"[107] was slid up and down by the staffman[108], in accordance with signals made by the leveller, until its centre was in the line of collimation prolonged; the staffman then read the height of the vane above the ground. The making the divisions on the staff so distinct that the leveller can read them himself is an invention of Mr. Gravatt.

The observations, or readings of the staff, taken by means of the level, are called *sights*.[109] When two sights only are taken from one station, one with the staff upon a point whose level has been ascertained, and the other with the staff upon a point whose level is to be ascertained, the former is called the *back-sight*[110], and the latter, the *fore-sight*.[111] When the levels of a series of points are taken with the level at one station, in order to make a continuous section, the first and last observations are the principal back and fore-sights respectively. Of the intermediate sights, each is a fore-sight relatively to the preceding sight, and a back-sight relatively to the following one. The first back-sight and the last fore-sight are the most important in point of accuracy, for any error committed in them is carried on through the whole of the remainder of the section.

Inasmuch as a truly horizontal surface is not plane, but spher-

[104] Nivellirinstrument. [105] Nivellirlatte. [106] Ablesung. [107] Zieltafel. [108] Lattenträger. [109] Visur; *line of sight* Visirlinie. [110] Rückvisur. [111] Vorvisur.

oidal, the line of sight of the level, when truly adjusted[112], does not exactly coincide with such a surface, but is a tangent to it. The height read upon a levelling-staff, therefore, is always greater than it would be if a horizontal surface were plane; and the quantity to be deducted is called the *correction for curvature.*[113] At distances not exceeding ten chains, the curvature of the earth may be neglected.—On the other hand, the line of sight, being the line along which light proceeds from the object looked at to the telescope, is not perfectly straight, being made slightly concave downwards by the refracting[114] action of the air. Hence the point seen on the staff apparently in the line of collimation produced, is below it, by an amount called the *error from refraction*[115], and thus the error arising from curvature is partly neutralized. The joint correction for curvature and refraction, to be subtracted from the reading of the staff, is on an average, $\frac{5}{6} \times \frac{(\text{distance in feet})^2}{41{,}778{,}000}$.

The *level field-book*[116] is kept in various forms, according to the practice of different engineers. In one of the most usual and convenient, each page is divided into seven columns, headed as follows:

Rise.	Back-sight.	Fore-sight.	Fall.	Reduced Level.	Distance.	Description of Object.

Levelling by the plane-table or by the barometer, is not to be relied upon for engineering purposes, except occasionally in taking flying levels. *Flying levels*[117] are observations for ascertaining the elevations of detached points of primary importance as regards the practicability[118] and cost of the work, and the selection of the line for it. Two classes of lines may be distinguished, whose positions and figures are of primary importance in determining the shape of the surface of a district—*ridge lines* or *water-shed lines*[119], and *valley-lines.*[120] A *pass*[121] is a place on a ridge-line lower than any neighbouring point on the same ridge-line, and might be described as a point where a ridge-line and a valley-line cross each other; passes are of most importance in the engineering of lines of communication, because they are in general the points at which ridges are to be crossed.

Contour-lines[122] are used as means of enabling a plan to give more complete information as to the figure of the surface of the ground than is possible by means of levels written in figures alone. A contour line is a line traversing all the points on the ground that are at a given constant height above the datum-level.[123] The

[112] justiren; *adjustment* Justirung. [113] Correction wegen der Erdkrümmung. [114] strahlenbrechend, s. *Technical Vocabulary*, ch. 19. [115] Fehler wegen der Refraction (Strahlenbrechung). [116] Nivellement-Feldbuch. [117] flüchtiges Nivellement, Geschwindnivellement; *checking level* Controlnivellement; *bench mark* Fixpunkt. [118] Durchführbarkeit. [119] Gratlinie, Bergrückenlinie, Wasserscheidelinie. [120] Thallinie. [121] Sattel, Joch. [122] Horizontalcurve, Höhencurve, Schichtenlinie. [123] Normalhorizont.

horizontal distance between two adjoining contour-lines being inversely as the tangent of the angle of inclination of the ground, is also inversely [124] as the depth of shadow to be used to express the steepness of the slope. "Hill-sketching" [125], as it is called, consists in shading the slopes of hills upon the ground according to this principle, with the pencil, by drawing horizontal lines parallel to the contour-lines, and with a degree of closeness proportional to that of the contour-lines themselves. Those pencil hatchings [126] are in fact intermediate contour-lines sketched by hand. In engraved plans the shading of hills is effected by means of hatched lines at right angles to the contour-lines, and following, therefore, the lines of steepest declivity.

RANKINE, *A Manual of Civil Engineering.*

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2. OF EARTHWORK.*

EARTHWORK [1] is of two kinds — excavation, or *cutting* [2], and filling, or *embankment.* [3] The term "earthwork", in its widest sense, comprises excavation in rock, as well as in looser materials of the earth's crust.

Earthwork gives way by the *slipping* [4] or sliding of its parts on each other; its *stability* [5] arises from resistance to the tendency so to slip. In solid rock that resistance arises from the elastic stress [6] of the material, when subjected to a shearing force; but in a mass of "earth", as commonly understood, it arises partly from their mutual adhesion, and partly from the friction [7] between the grains. But the adhesion of earth is gradually destroyed by the action of air and moisture, and of the changes of the weather, and especially by alternate frost and thaw; so that its friction is the only force which can be relied upon to produce permanent stability.

The *permanent stability* [8] of earth, which is due to friction alone, is sufficient to maintain the side either of an embankment or of a cutting at an uniform slope, whose inclination to the horizon is the *angle of repose* [9], or angle whose tangent is the *co-efficient of friction.* [10] This is called the *natural slope* [11] of earthwork. The customary mode of describing the slope of earthwork is to state

124 sich umgekehrt verhalten wie. 125 "Hügelskizziren." 126 *to hatch* schraffiren, *hatchings, hachures* Schraffirung, *Lehmann's diapason* der Lehmann'sche Böschungsmassstab.

1 Erdarbeit. 2 (Aushebung oder) Einschnitt. 3 (Auffüllung oder) Damm. 4 Abrutschen. 5 Stabilität, Standfähigkeit. 6 Spannung; *shearing force* Abscheerungskraft, s. T. II, Nr. 1. 7 *friction* Reibung, s. T. II, Nr. 8, 16. 8 dauernde Standfähigkeit. 9 Ruhewinkel. 10 Reibungscoefficient. 11 natürliche Böschung.

* S. *Technical Vocabulary*, ch. 55, Nr. 2.

the ratio[12] of its horizontal breadth to its vertical height, which is the *reciprocal*[13] of the tangent of the inclination.[14] The most frequent slopes of earthwork are those called $1\frac{1}{2}$ to 1,[15] and 2 to 1.[16]

The presence of moisture in earth to an extent just sufficient to expel the air from its crevices, seems to increase its co-efficient of friction slightly; but any additional moisture acts like an unguent[17] in diminishing friction, and tends to reduce the earth to a semi-fluid condition, or to the state of mud. Hence it is obvious that the frictional stability of earth depends to a great extent on the ease with which the water that it occasionally absorbs can be drained away.[18] The safest materials are shivers of rock[19], shingle[20], gravel[21], and clean sharp sand, for those materials allow water to pass through without retaining more than is beneficial.

The boundaries[22] of a piece of earth-work in general are as follows:—

1. The *base*, *forming*, or *formation*[23], being a surface nearly, and sometimes exactly horizontal, which forms the bottom of a cutting, or the top of an embankment.

2. The original surface of the ground, which forms the top of a cutting and the bottom of an embankment.

3. The *sides*, or *slopes*[24], which connect the base with the natural surface, and whose inclination is the steepest consistent with the permanent stability of the material.

The *half breadth*[25] of a piece of earthwork means the horizontal distance from a given point in the *centre line*[26] of the base to one edge of the cutting or embankment; and although it is called "*half*-breadth", it is very generally different at opposite sides of that centre line. Each half-breadth consists of two parts: the real half-breadth of the base, which is fixed by the design of the work, and the horizontal breadth of one slope, which is to be found by calculation or by drawing. The half-breadths to the right and left of the centre line at a given point, being each increased by the breadth required for fencing[27], give the *total half-breadths* at that point; and these being added together, give the *total breadth* of the land to be taken. From a series of those breadths, the *areas of land*[28] to be taken may be calculated.

Equalizing earthwork[29] is a term applied to the process of so adjusting the formation level of an intended work, that the earth from the cuttings shall be as nearly as possible sufficient to make the embankments, and no more. In most cases it is essential to economy in the cost of the work; for any surplus of embankment

[12] Verhältniss. [13] reciproke Wert. [14] Neigung(swinkel). [15] $1\frac{1}{2}$-füssig. [16] 2-füssig. [17] Schmiermittel. [18] abziehen, drainiren. [19] Felssplitter. [20] Gerölle, Geschiebe. [21] Schotter, Kies. [22] Begrenzung. [23] Sohle, Planum, Unterbaukrone. [24] (Seite oder) Böschung. [25] Ausladung. [26] Mittellinie (Bahnaxe). [27] Einfriedigung. [28] Grundfläche. [29] Ausgleichung der Erdmassen.

over cutting must be made up from "*side cutting*"[30]; and the earth from any surplus of cutting over embankment must be formed into "*spoil banks*"[31]; both of which works involve additional cost for labour and land. The *distribution of earthwork*[32] means the arrangement by which the materials obtained from different parts of the cuttings are distributed amongst different parts of the embankment, so as to incur the least possible expenditure[33] of labour in the *leading*[34] or conveyance of the earth.

The *temporary fencing*[27], erected before the earthwork is commenced, should enclose all the ground required for the undertaking; it usually consists of posts[35] and rails[36] of larch or oak.

If the soil is wet, *a catchwater drain*[37] may be made at the same time with the temporary fencing, at one or both sides of the earthwork, commencing at its outfall[38] into an existing main drain[39] or water course[40], and working upwards. When the ground has a sidelong slope the catchwater drain is indispensable at the up-hill side[41] of the earthwork. It may be an open ditch[42]; or it may be an underground drain[43], built of stone or brick, or made of earthenware tubes, with broken stone[44] or clean gravel above it.

The soil or vegetable mould should be *stripped*[45] from the side of an intended piece of earthwork, and laid down near the fence, in order that it may be afterwards used to re-soil the slopes.

Cutting.—A cutting is usually commenced (if the earth will stand for a time with vertical sides) by making a "*gullet*"[46], or vertical-sided excavation, wide enough to contain one or more lines of temporary rails[47] for the passage of earth wagons[48]. The head or advanced end of a cutting of considerable depth, and the parts of its sides whose slopes have not been finished, consist, while the work is in progress, of a series of steps or stages, called "lifts"[49], rising one above another by six or eight feet, or thereabouts, the excavators working at the faces[50] of these lifts so as to carry them on together. From faces at the end or sides of the gullet, the earth is shovelled directly into the wagons; from the other faces of the cutting, the earth is wheeled in barrows[51] along planks to points from which it can be tipped[65] into the wagons.

The *labour of earthwork* in ordinary cases consists of *getting*[52], or excavating; *filling*[53] into barrows or wagons; *wheeling*[54] in barrows; *leading*[54] in wagons; and *teeming* or *tipping*[55], that is, depositing[56] the earth in the embankments where it is to rest. The labour of *getting* the earth depends mainly upon its adhesion. Loose

[30] *side-cutting* Anschnitt, *borrowing* Seitenentnahme, *borrow pit* Füllgrube, Materialgrube. [31] Ablagerung, Aussatzboden. [32] Verteilung der Erdmassen. [33] Aufwand. [34] Verführung. [35] Pfosten, Säule. [36] Riegel, Latte. [37] Entwässerungsgraben, Schutzgraben. [38] Ausmündung. [39] Hauptgraben. [40] Wasserlauf. [41] Bergseite. [42] Graben. [43] Drain. [44] Steinschlag. [45] abschürfen, abdecken. [46] Schlitz. [47] provisorische Schienen. [48] Erdtransportwagen, Rollwagen. [49] Etage, Stufe. [50] Stirnfläche. [51] Schubkarren. [52] Gewinnung. [53] Aufladen. [54] Verführen, Transport. [55] Anschütten oder Umkippen. [56] ablagern.

sand and gravel, soft vegetable mould, and peat can be dug with the shovel[57] or the spade alone; stiffer kinds of earth require to be loosened with the pick[58] before being shovelled into barrows, and in some cases, with crowbars[59], wedges[60], or stakes; the hardest kinds of rock, especially if free from natural fissures[61], need *blasting*[62] by gunpowder. *Wheeling* in barrows is performed upon planks, whose steepest inclination should not exceed 1 in 12, unless the men are assisted by means of ropes[63] and winding[64] machinery. *Leading* is performed upon light temporary rails, in wagons called "earth-wagons"[48], whose bodies can be tipped[65] over by turning on a pair of horizontal trunnions[66], so as to empty the earth out: they are drawn by horses or by small locomotive engines. In order to execute an excavation with speed and economy, it is necessary to fix correctly both the absolute and the proportionate numbers of pickmen, shovellers[67], and wheelers, or barrowmen[68], so that all shall be constantly employed. Earth is designated as "earth of one man", if one shoveller can keep one line of wheelers at work; "earth of a man and a half", if two shovellers and a pickman are needed to keep two lines of wheelers at work; and generally "earth of so many men", according to the number of shovellers and pickmen together who are required to keep one line of wheelers at work. The labour of excavating is often considerably lessened, especially in widening the gullet at the sides, by undermining large masses of earth from below, and loosening them by driving stakes behind them from above; this is called "falling".[69]

At the foot of each slope of a cutting it is almost always necessary to have a longitudinal drain called a *side-drain*.[70] It may be a small open ditch, or a channel pitched and faced with stone, or a covered stone or brick drain, or a line of tubes with broken stone or gravel above. *Benches*[71] on the sides of cuttings are small platforms, level transversely, seldom exceeding about six feet in breadth. They are sometimes used in very deep cuttings, for the purpose either of intercepting the fall of boulders and pieces of rock from the higher slopes, or of facilitating the drainage.[72]

The prevention of *slips*[73] is promoted by efficient ordinary drainage. When ordinary methods of drainage are insufficient, other expedients must be adopted, such as the following:—To face[74] the slope with a well-packed layer of stones laid dry; to build at the foot of the slope, so as at once to support and drain it, either a dry stone *retaining wall*[75], or a wall of brick or masonry laid in mortar[76], backed with a vertical layer of dry stones; to intercept[77] underground waters on their way towards the slope,

57 Schaufel. 58 Spitzhaue, Pickel. 59 Brecheisen. 60 Keil. 61 Spalte. 62 Sprengen. 63 Seil. 64 Aufwinden. 65 umkippen. 66 Zapfen. 67 Schaufeler, Auflader. 68 Kärrner. 69 Loskeilen. 70 Seitengraben. 71 Berme. 72 Entwässerung. 73 Erdrutsch. 74 verkleiden. 75 Stützmauer. 76 Mörtel, s. Teil I, Nr. 21. 77 auffangen.

by means of a drift or mine.[78] The stability of battering-faced[79] retaining walls and of walls with a "curved batter"[80] is greater than that of upright rectangular walls. Retaining walls may have their stability increased by being tied or anchored[81] by iron rods[82] to vertical or nearly vertical plates imbedded in a firm stratum of earth at a distance behind the wall. In order to let water escape from behind the wall, it has small upright openings through it called "weeping-holes".[83] In walls of great size, both back[84] and face[85] may be built of block-in-course[86], or the face of ashlar[87], and the back of block-in-course, the "heart"[88] being of coursed rubble[89], or of beton[90] or strong concrete. A "surcharged[91] retaining wall" is a wall for supporting a bank of earth which rises from the top of the wall at the natural slope for a certain height called the "height of the surcharge"[92], beyond which it is horizontal.

Embanking.—An embankment may be made in three ways: in one layer[93], in thick layers, or in thin layers. The last-mentioned process consists in spreading the earth in horizontal layers of from 9 inches to 18 inches deep, and ramming[94] each layer. Being a laborious and tedious process, it is used in special cases only, of which the principal are, the filling behind retaining walls, behind wings and abutments[95] of bridges and culverts[96], and over their arches[97], and the embankments of reservoirs for water. Embankments are generally made in one layer, this being the cheapest and quickest method, consistent with stability.

When the natural ground has a steep sidelong slope, it is, in general, necessary to cut its surface into steps[98] before making the embankment, in order that the latter may not slide down the slope.

Embankments subside or *settle*[99] after their first formation, to an extent which varies considerably for different materials; allowance for this settlement must be made in constructing the embankment. The slopes are to be dressed[100] to smooth and regular surfaces, and covered with a layer of soil, which is sown with grass-seed. Slopes which are exposed to still water may be faced or "pitched"[101] with dry stone about a foot thick.

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[78] Stollen. [79] mit abgeschrägter Vorderseite, mit geböschter Stirnseite. [80] mit gekrümmter Vorderfläche. [81] verankern. [82] Eisenstange. [83] Ablaufloch. [84] Rücken, Rückseite. [85] Haupt, Stirn(fläche). [86] Schichtenmauerwerk. [87] Haustein, Quader. [88] das Innere. [89] aus unregelmässigen Bruchsteinen. [90] s. T. I, Nr. 21. [91] überschüttet. [92] Ueberschüttungshöhe. [93] Schicht. [94] feststampfen. [95] Widerlager. [96] Durchlass. [97] Bogen. [98] Stufe; *to step* terrassiren. [99] sich setzen; *settlement* Setzung, Sackung. [100] planiren. [101] abpflastern.

3. ROADS.

ROADS [1] are artificially-formed ways between distant places, and being among the first means of personal communication, their formation and treatment, as duties of the engineer, are of the highest importance. The efficiency of roadmaking [2] requires that the surface [3] of the road shall be preserved in a durable condition, and adapted for the kind of traffic [4] to be conducted upon it; and, therefore, the construction of the road, both as regards its superstratum [5] or surface, and substructure [6], its dimensions and inclination [7], or declivity, are equally to be determined with reference to the particular kind of wear to which it will be subjected. Thus the weights that will pass over the road will make it necessary that it possess greater or less firmness and solidity, while the rigidity or hardness of its surface affects the power required for moving bodies, or the draught. [8] The vertical inclination [9] of the road has an influence upon the draught, and is also limited by the class of traffic. The old Roman roads, for instance, designed for the passage of animals only, were laid with inclinations of great steepness, and with reference only to the directness of their course. The use of wheel carriages [10] imposes limits to the steepness which cannot be exceeded either with safety or with economy of power. The most improved form of road—the railway—restricts the steepness or inclination still further, the propelling power employed being found to become expensive in a rapid ratio in proportion to the departure of the surface on which it is exerted from a horizontal plane. [11] The qualities of a good road are, solidity of structure,—hardness of surface,—levelness of inclination, and sufficiency of width [12] for all its purposes. To insure the permanence of these qualities, the formation and the drainage [13] of the road are required to be complete, while the several means to be adopted will be partly determined by the kind of materials at command. Experiments made to ascertain the force of traction [14] on different kinds of roads, have shown that this force is nearly in exact proportion to the strength and hardness of the road. Thus the draught on a

[1] *Line of land carriage* Landverkehrsweg, *line of conveyance* (oder *communication*) Verkehrslinie, *road* Strasse, *railway, railroad* Eisenbahn, *tramway* Strassenbahn, *stone tramway* Steinbahn; *level crossing* Niveaukreuzung, *selection of line* Wahl der Linie. Ueber Erdarbeiten s. Nr. 2; Tunnels Nr. 10; Brücken Nr. 17 ff. [2] Strassenbau. [3] Oberfläche. [4] Verkehr. [5] *superstructure, permanent way* Oberbau. [6] oder *formation* Unterbau, *formation-level* Planum. [7] Neigung. [8] Zug(kraft). [9] oder *gradient* Gefälle, Steigung, *ruling gradient* (massgebende Steigung) = *steepest rate of inclination which prevails generally on the line; easy (steep) gradient* schwache (starke) Steigung. [10] Räderfuhrwerk, Wagen; *vehicle* Fuhrwerk. [11] Ebene. [12] oder *breadth* Breite; *carriage-way* Fahrweg, *footway* Gehweg, Fussweg, *subway* Tunnel; *fence* Einfriedigung; *centre line* Axe. [13] *drainage* Entwässerung, *side-drain* Seitengraben, *gutter, channel* Rinne, *mitre drain* Sickerschlitz, *open ditch* offener Graben, *sewer* Siel, *gully-hole* Einfallsschacht; *to collect the surface-water* das Tagwasser sammeln. [14] oder *tractive force* Zugkraft.

well-made pavement[15] is half that upon a broken stone[16] surface, or old flint road, and less than a quarter of the draught upon a gravel road.[17] If the strength or solidity of the foundation[18] be increased, the draught is reduced. Thus, if the broken stone road be laid upon a rough pavement foundation, the draught is reduced one third, and a similar reduction is effected by laying a bottoming[18] of concrete formed of cement and gravel. The external forces by which the motion of bodies upon roads is retarded, and the draught or power required consequently augmented, are collision, friction, gravity, and the atmosphere. Collision is occasioned by the hard protuberances and irregularities of surface of the road meeting the wheels, and thus diminishing the momentum of carriages. The resistance arising from collision is proportional directly to the load and the height of the obstacle to be surmounted, and inversely to the diameter of the wheels of the carriage in which the load is borne. Professor Leslie has defined the resistance which friction causes to consist "of the consumption of the moving force, or of the horse's labour, occasioned by the soft surface of the road, and the continually depressing of the spongy and elastic substrata of the road." From the formulæ which have been deduced upon the extent of this resistance, it is evident that it is caused by the wheels sinking into the ground, and is proportional directly to the load, and inversely to the width of the wheels. The resistance produced by gravity is evidently in proportion to the steepness of the road, being nothing on a perfectly horizontal plane, and augmenting as the inclination approaches the perpendicular. The force of the air in resisting the motion of loads upon roads may be understood from the experiments which are given in Smeaton's Reports, and from which it appears, that upon a surface of one square foot this force equals 1 lb. when the velocity of the wind is at the rate of 15 miles per hour; and that this force becomes equal to 12 lbs. when the air moves at the rate of 50 miles an hour, constituting a storm.

In designing a road, a correct survey[19] of the proposed line, with the exact relative levels of all parts of its present surface, is the first requisite, and upon this the engineer proceeds to consider the propriety of deviating in one direction or another, in order to attain better levels, or to equalise the earth-works[20], so that the quantity excavated in one part may suffice to embank[20] an adjacent portion and thus reduce the distances to which the soil must be removed. In determining the inclinations of the surface, facts proved by experience should be consulted, from which the rule may

[15] *stone pavement* Steinpflaster, *paving-stone* Pflasterstein, *beetle or rammer* Pflasterramme, *rubble pavement* Bruchsteinpflaster, *asphalt(ic) pavement* Asphaltpflaster, *wood(en) pavement* Holzpflaster. [16] oder "*(road) metal*" Steinschlag, Schotter; *broken stone road* Schotterstrasse. [17] Kiesweg. [18] Grundbau, Unterlage. [19] s. Nr. 1. [20] s. Nr. 2.

be inferred that an inclination of 1 in 35 is that which admits of horses moving with perfect safety in a fast trot. Valleys are required to be crossed by bridges and viaducts, or by solid embankments[20] of earth, and streams and rivers are also to be passed, and thus the design and execution of an extended length of road requires much engineering skill.

WEALE-HUNT, *Dictionary of Terms.*

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4. RAILWAYS.

THE origin of these now vast undertakings is traced to a contrivance for simplifying the transit of coal from the mines in Northumberland and Durham to the places of shipment on the Tyne and Wear. The invention consisted of a double parallel line of wooden beams or trams[1] fixed to the ground, and furnished with flanges to prevent the wheels of vehicles from slipping aside. Along these flanged beams waggons were drawn by horses with such comparative ease, that instead of a load of 17 cwt. by a common road, a load of 42 cwt. could now be drawn by a single horse. These new thoroughfares, called tramways, were made across fields, the proprietors of which received a certain rent for the way-leave or use made of them — which term, way-leave, is still employed in arrangements of this kind. To the coal districts of the north of England, therefore, is indisputably due the simple yet meritorious contrivance which, from less to more, led to the modern railway, with all its wonderful machinery; nor is it useless to note, that the invention, in its early stages, owed nothing to men of education or high scientific attainments, but was mainly the work of obscure mechanics and illiterate enthusiasts.

The date of the invention of tramways is uncertain, but by good authorities it is referred to the period between 1602 and 1649. From the northern coal districts it gradually came into use in other mining districts in England, as also in the south of Scotland. The 17th c. was not favourable to mechanical improvement. Not till

[1] *Tram-road*, a road prepared for easy transit of trains or wagons, by forming the wheel-tracks of smooth beams of wood, blocks of stone, or plates of iron. This word is said, by some, to be derived from the name of Mr. *Outram*, a gentleman extensively connected with the collieries in Newcastle, England, these roads having been called at first, it is said, *outram* roads; but the name is probably derived from *tram*, a coal-wagon, railroads having been first constructed, and being still extensively used, for such wagons.— *Tram*, a coal-wagon used in some parts of England, especially at Newcastle; the shaft of a cart; one of the rails or tracks of a tram-road. WEBSTER. — *Tram* Kohlenwagen (four-wheeled truck for carrying a corve, hutch, or basket on a pair of rails in a mine, *Knight*), Grubenschiene mit vorspringendem Rand, Kranzschiene; *tramway* oder *tramroad* Grubenbahn, Pferdebahn, Strassenbahn; *flange* Flantsche.

about 1700 was there any marked advance on the original tramway. The first step was the clothing of the wooden beams with long slips of iron, to prevent excessive tear and wear.[2] This also being found defective, a second and more complete improvement, about 1700, was the substitution of cast-iron rails[3] fixed in parallel lines on cross wooden sleepers.[4] This species of railway became pretty general in mining districts between 1745 and 1775. In the former of these years, one was in operation in Scotland — namely, a short coal-line from Tranent to Cockenzie, which General Cope selected as a position at the battle of Prestonpans. Though now considerably improved, railways did not attract attention as being suitable for general traffic. The success of canals not only turned the public mind in that direction, but raised up a powerful canal interest, which viewed the progress of railways with extreme jealousy and ill-will.

The use of cast-iron rails led to an improved method of traction. Instead of employing a single large waggon, the plan of linking together a series of smaller waggons was adopted — the germ of the modern train.[5] The next improvement consisted in putting flanges on the wheels instead of the rails, by which great facility of transit was afforded. The draught still continued to be executed by horses; but as the railway system seemed to possess immense capabilities of expansion, many minds laboured in devising schemes to substitute steam-apparatus. The invention of the locomotive[6], like that of railways, was the work of successive geniuses.[7] WATT had shown the practicability of fixed steam-engines[8]; what was now wanted was an engine that would travel by its own internal impulse. The merit of inventing a self-acting steam-carriage[9] is allowed to be due to RICHARD TREVITHICK, a clever but eccentric engineer. In 1802, he took out a patent for a steam-carriage, and this novel machine he exhibited to large crowds of admiring spectators on a piece of ground near London. Immediately afterwards, he adapted his carriage for the drawing of waggons on railways, a duty which it successfully executed on the Merthyr-Tydvil Railway in 1804. This was the first locomotive; but it was far from perfect. It drew only ten tons of bar-iron[10] at the rate of five miles an hour. Trevethick did not remain in England to improve on his invention, nor did the moderate achievements of his machine immediately induce others to make any distinct advance on his ingenious contrivance. For this lethargy there were various causes; but the principal consisted in a universal belief among engineers[11], that the locomotive could not be expected to gain great speed, to ascend a moderate incline[12], or to

[2] Abnutzung. [3] gusseiserne Schiene, s. Nr. 5. [4] Schwelle, s. 50. [5] Eisenbahnzug. [6] s. Nr. 6 u. T. II, Nr. 31 fg. [7] s. T. I, Nr. 1, 2. [8] feststehende Dampfmaschine, s. T. II, Nr. 30. [9] Dampfwagen; *self-acting* selbsttätig, selbstwirkend. [10] s. T. II, Nr. 2. [11] *engine* Maschine (über *engine* und *machine* s. T. II, Nr. 30, Anm.), *engineer* Ingenieur, *engineering* Ingenieurkunst, -wesen, *civil engineer* Civilingenieur, *civil engineering* (s. Nr. 1, Anm.) Bauingenieurwesen, *mechanical engineer* Maschineningenieur. [12] Steigung.

draw a heavy load, unless the wheels were provided with a cogged rim [13] to work on a corresponding rack [14] along the rails. Numerous schemes were made the subject of patents to overcome this imaginary difficulty — a circumstance which gives one a poor opinion of the state of engineering knowledge at the beginning of the 19th century. That locomotives running with smooth wheels on smooth rails, by mere weight and friction, as exemplified by Trevethick, could draw heavy loads up a moderate incline, was at length, in 1811, established as a fact by Mr. Blackett, a coal-proprietor, on the Wylam Railway. The means for imparting speed alone remained to be given.

Locomotive power was employed by GEORGE STEPHENSON on the Killingworth Railway in 1814, and with such success that it was afterwards applied on the Stockton and Darlington Railway [14a], for which the first act of parliament was passed in 1821. In this last undertaking, Stephenson was encouraged by the generous and enlightened aid of Edward Pease, a member of the Society of Friends, whose name will always be associated with the history of railway enterprise. The Stockton and Darlington was the first railway in which carriages travelled with passengers; yet, even with the measure of success so secured, the locomotive was still an imperfect machine, for its rate of progress continued to be little faster than the walk of a horse. Acceleration was now the grand desideratum, and it was attained by using a very simple contrivance — that of sending the waste steam up the chimney, so as to cause a powerful draught [15] in the fire; a rapid generation of steam was the consequence, and by this appliance, along with the multitubular boiler [16], the machine shot forward with an energy hitherto unknown.

It certainly seems very strange, that notwithstanding the proved feasibility of railways, the public at large could not be stimulated to give any heed to the subject. It was shown in this, as in the analogous case of steam-boats, that the world may remain sceptical of an invention long after it has been practically established beyond cavil. The idea of extending railways over the kingdom for general traffic [17], was perhaps first conceived by Thomas Gray of Nottingham, who, full of enthusiasm, besieged the public, and memorialized the government on this his favourite project, between 1820 and 1824. A work, embodying his views, *Observation on a General Iron Railway*, &c., was published in 1820. Gray's ardent notions met with little favour. Unfortunately, he was no mechanic, and, seemingly unacquainted with the advances which had been made, laboured under the old exploded belief that locomotives must have cogged wheels. After Gray, there appeared another projector, William James of London, who, in 1822, endeavoured, without success, to

[13] *rim* Radkranz, *cog* eingesetzter Radzahn, Kamm, *cog-wheel* Kammrad, s. Teil II, Nr. 6. [14] Zahnstange. [14a] s. Nr. 10. [15] Zug, s. T. II, Nr. 27. [16] s. T. II, Nr. 31. [17] Verkehr.

establish a railway between Liverpool and Manchester. Opposition caused his plans to be laid aside. The next and more fortunate projector was Joseph Sanders of Liverpool. He issued the prospectus of a railway from Liverpool to Manchester, 29th October 1824; and this line, surveyed[18] by Stephenson, was, after much unworthy opposition, and some changes of route, sanctioned by the legislature. It was formally opened for traffic[19], September 15, 1830. Provided with some of George Stephenson's improved locomotives, the success of the line was immediate and complete—in fact, the great railway system was inaugurated.

Now, properly speaking, began that course of commercial enterprise, unregulated, and often wasteful, which has since assumed such importance. Refraining from all control over railway operations, the government left speculators to carry lines anywhere or anyhow that parliament could be persuaded to sanction. The result, as is well known, has been in many places a complication of competing lines on a principle of economy or enlightened foresight. Abandoned, as it were, to the audacity of promoters, and the mere brute force of capital, schemes, good, bad, and indifferent, had to fight their way at a cost almost exceeding belief; while at the same time allowing circuitous lines to places which are afterwards, in a great measure, superseded by others more direct.

Railways were at first detached undertakings, between one large town and another, but now many of the companies have for mutual advantage amalgamated in groups; and in a number of cases lesser lines have been leased to companies of larger means. In this, as in most other commercial concerns in Great Britain, the tendency is to concentrate business in the hands of monopolists possessing large capital, or at least those having a great capacity and disposition to borrow. One of the advantageous results of a union of railway interests is, that passengers[20] are able to procure "through-tickets"[21] to carry them forward for hundreds of miles without delay or change of carriage[22]; but it is not less conspicuous that the "railway interest" has become a formidable power in the state, and is able to carry lines almost anywhere, in disregard of land-proprietors or town-authorities, as if the destruction of rural amenity and wholesale ruin of dwellings were matters of perfect indifference. Making every allowance, therefore, for the high social value of the railway system, it has certainly reached a point of despotic overbearance that requires some species of control more effectual than that which is embraced in the irregular action of parliamentary committees or of the Board of Trade.

Construction.[23]—Railways in the United Kingdom are of two

[18] vermessen, s. Nr. 1. [19] Verkehr. [20] Passagier, Reisender. [21] direktes Billet. [22] Wagenwechsel. [23] *railway construction* Eisenbahnbau.

kinds — *double* and *single.*[24] The double consists of two lines of rails — an *upline*, conducting towards, and a *down-line*, leading from the metropolis or principal centre of traffic. By far the larger number of lines are of this double variety. Single lines, with places where trains may pass each other, are mostly of recent construction, and have received chief development in Scotland. Whether double or single, all the lines are enclosed by fences — stone-walls, palings, hedges, or stretches of wire. At the chief *terminus*[25], there is a group of buildings for locomotives, &c. Along the lines, there are *stations* at distances of two or ten miles. At the termini and stations, there are raised *platforms*[26] for the accommodation of passengers. The principal stations are under cover, and are provided with *waiting-rooms.*[27] When lines pass through a town, they are carefully secluded. Recently, there have been great improvements as regards fixed signal-posts, and the processes for *shunting*[28] trains.

The construction of a railway is the business of contractors[29], who execute the works by estimate, according to the plans and specifications of the engineers. A railway contractor is a capitalist with a practical knowledge of earth-digging, blasting[30] rocks, pumping, boring and building tunnels, erecting bridges, and other rough operations. He possesses a stock of wheelbarrows, picks, and shovels, carts, earth-wagons, horses, light rails and sleepers for temporary purposes, and other professional machinery, including one or more locomotives for dragging materials.[31] Acting himself as commander-in-chief, he has subordinates called time-keepers, foremen, gaugers, and under-gaugers placed over detachments of operatives. The operatives are a remarkable class of men. Originally from Lincolnshire and Lancashire, they are popularly known as *navvies*[32], from having been engaged in excavating navigable canals. The genuine navvy is an interesting specimen of a strong-built, hearty, industrious, and illiterate English rural labourer; his dress, a round felt-hat, coloured plush waistcoat, loose flannel jacket, corduroy breeches, and laced quarter-boots — appetite for beef, fried ham, and ale immense. With muscular strength corresponding to his appetite, the navvy is a proficient at using the pick, shovelling earth, and handling a wheel-barrow, which, with a load of one or two hundredweight, he trundles along a plank, and tips over with uncommon dexterity. Navvies sometimes labour in bands, called *butty-gangs*, by

[24] *single* eingleisig, einspurig, *double* zweispurig, *line*, *track* Gleis, *double track* Doppelgleis, *main track*, *through line* Hauptgleis. [25] *terminus* (pl. *termini*, s. Teil I, Nr. 1, 2) Endstation, *(intermediate) station* Zwischenstation, *passenger (goods) station* Passagier-(Güter-) Bahnhof, *goods depôt* Güterhalle. [26] Perron. [27] Wartesaal. [28] *to shunt* auf ein anderes Gleis bringen, *shunting* Ausweichung, Weichestelle, *switch* Weiche, *crossing* Kreuzung, *frog* Herzstück, *traverser* Schiebebühne, *turn table* Drehscheibe. [29] Unternehmer. [30] Sprengen. [31] s. Nr. 2 "*Earthwork*". [32] Erdarbeiter, Eisenbahnarbeiter. *Navvy* (abridged from *navigator*); originally, a labourer on canals for internal navigation, and, hence, a labourer on other public works, as in building railroads, embankments, and the like. WEBSTER.

piece-work, and are known to draw large sums, but more generally they are employed at days' wages—their time being kept by a clerk to ensure steadiness of work. At a distance from towns, they and their families live in rudely-constructed huts, near which is placed a store, for the sale of articles they may require. Their pay is usually paid every fortnight, on which occasion much of their earnings is heedlessly dissipated, and sometimes serious brawls, calling for the interference of the police, occur.

Curves[33] *and Gradients.*[34]—Engineers endeavour to render their lines as level and straight as possible, circumstances often necessitate the use of considerable curves and gradients. As a general rule, there are few curves of less than three-eighths of a mile or 30 chains'[35] radius; when they are employed, the exterior rail is super-elevated[36], to counteract the centrifugal force[37], otherwise a quickly moving train might leave the rails.[38] Gradients being expensive to work according to their degree of inclination[39], few are more steep than 1 in 60, though 1 in 30 is not unknown. When the gradient is steeper than this, stationary engines[8] are usually employed.

Gauge.[40]—In the early stage of railway operations, the gauge or width between the rails excited considerable discussion. When way-leaves, or tramways, were introduced in the coal districts, their gauge was adapted to the common road-wagons that were to be put upon them, and it happened that the gauge between the wheels of these waggons was 4 feet $8\frac{1}{2}$ inches. Accustomed to this width, George Stephenson believed that it "was most economical in construction, not only as regarded the engines and carriages, but more particularly of the railway itself." This gauge was accordingly adopted on most of the earlier-made railways, and, notwithstanding the keen contests of engineers, who were generally favourable to a 5 feet or 5 feet 3 inches gauge—Brunel contending for 7 feet—this original 4 feet $8\frac{1}{2}$ inches gauge—measured from the inside of one rail to the inside of the other—was irrevocable to all the railways in England and Scotland, the Great Western and certain branches excepted, on which the gauge was regulated at 7 feet. Owing to inconvenience in communicating with other lines, and from other reasons, the Great Western has now relaid its lines on the standard gauge.

Ballast.[41]—This is the name given to the mass of broken stones

[33] *curve* Curve, *radius of curvature* Krümmungshalbmesser, *curve of 500 feet radius, ten-degree curve* Curve von 500 Fuss Radius, von 10 Grad Centriwinkel, *circular curve* Kreiscurve, *compound curve* Korbeurve, *reversed curve* Contracurve, *laying out curves* Curvenabstecken. [34] Steigung, resp. Gefäll; *gradient-post* Gradientenzeiger, *change of gradient* Gefällswechsel. [35] s. Nr. 1, 36. [36] überhöhen; *super-elevation of the outer* (oder *exterior*) *rail* Ueberhöhung der äussern Schiene. [37] Centrifugalkraft. [38] *to leave the rail* entgleisen, *derailment* Entgleisung, *collision* Zusammenstoss. [39] Neigungsgrad. [40] *gauge* Spurweite, *standard gauge* Normalspurmass, *narrow-gauge railway* schmalspurige Bahn. [41] Ballast. Bettungsmaterial.

or dry gravel on which the sleepers are placed, and which serves to keep them steady. Material for ballast is generally got in the cuttings[31] or near the line, but is often brought a considerable distance. The term *ballast* originated in the practice of using the gravel-ballast emptied from the ships in the Tyne, for the tram and railways in the neighbourhood of Newcastle.

Rails.[42]—Rails are generally of wrought iron, but *steel-rails*[43] are coming now into use where there is a continuous heavy traffic. The rails differ in shape and weight. The most common form is the '*double-headed*'[44] rail, which is reversible.[45] Another form, which was once used on the Great Western for the broad-gauge line, is known as the '*bridge-rail*'[46]; and a form frequently used on the continent, and generally on narrow-gauge[40] lines, has a flat base formed by a flange on each side of the vertical *web.*[47] The last two descriptions do not require *chairs*[48], but are fastened directly to the *sleepers* by *spikes.*[49] Rails are generally 21 or 24 feet long, and for light railways vary in weight from 20 to 45 lbs., and for heavy lines from 60 to 80 lbs. per lineal yard. *Cross sleepers*[50] are laid at 2 feet 6 to 3 feet 6 inches apart, usually about 3 feet, and on these sleepers the *chairs* of cast-iron are fixed and held firmly down by iron spikes driven into the sleepers. The ends of the rails are now almost always joined together by a massive plate of malleable iron placed on each side called a *fish-plate*[51]; two of them are used at each *joint*[52], and are bolted together by four strong bolts[53] passing through the rails. In the joining of the rails end to end, to make a smooth surface, great care is bestowed; perfect steadiness in the required line of direction is secured by means of wooden wedges[54] acting on the rails and the chairs.

Hitherto, the sleepers have been of seasoned[55] native larch, as the most durable, but latterly, from the growing scarcity and cost of this article, sleepers have been made of imported timber from ports in the Baltic. They are sometimes *creosoted*[55] to render them durable. Many patents have been taken for methods of dispensing with wood sleepers and substituting some more lasting material.

Tunnels and Viaducts.—*Tunnels*[56] are avoided as far as possible, for, besides their costliness, they, if long, necessitate the constant use of lamps in the carriages. They are made only when the excavations would be more than 60 feet in depth, or when

[42] *rail* Schiene, s. Nr. 5. [43] Stahlschiene. [44] zweiköpfig. [45] *to reverse* umwenden. [46] Brückenschiene. [47] Steg. [48] *chair* Stuhl, *joint (intermediate) chair* Stoss- (Zwischen-) Stuhl. [49] Hakennagel. [50] *sleeper* Schwelle, *cross-sleeper* Querschwelle, *longitudinal sleeper* Langschwelle, *joint sleeper* Stossschwelle, *intermediate sleeper* Zwischen- oder Mittelschwelle. [51] Lasche; *to fish* verlaschen. [52] *joint* Stoss, *suspended (supported) joint* schwebender (ruhender) Stoss, *fish-joint* verlaschter Stoss. [53] Bolzen; *screw-bolt* Schraubenbolzen. [54] Keil. [55] s. Teil II, Nr. 3. [56] Tunnel; *tunnelling* Tunnelbau, s. Nr. 11.

land-proprietors force their adoption, in order to spare the amenity of grounds near a mansion. For this latter reason, some short tunnels are known to have cost railway companies as much as £ 50,000. Latterly, the execution of underground[57] railways in the metropolis has offered examples of tunnelling more extensive than were previously known in England, and at the same time popularized a method of subterranean[57] transit almost as marvellous as anything in the way of viaducts. All other tunnels have been cast into the shade by that through the Alps near Mont Cenis. The highest summit of the section immediately over this tunnel is 9527 feet, and the summit-level of the tunnel, 4246 feet—about the height of Ben Nevis[58]—above the level of the sea.[59] It was completed in 13 years, cost about £ 200 per lineal yard, the total length being 7·6 miles, and was opened on the 26th December 1870. The time occupied in passing through the tunnel by train is 25 minutes. The St. Gothard Tunnel[60] is a still greater undertaking.

The work of tunnelling has been greatly expedited, and its cost much reduced, by the invention of rock-boring machines.[61]

Viaducts[62] are frequently of stone, and of handsome architecture, but now commonly of malleable iron girders[63], of various forms, set in stone or iron piers.[64] In the construction of viaducts, there is a growing boldness of conception, originating with the success of the famed railway viaducts across the Menai Street[65], the river Tamar, and the St. Lawrence.[66] The following are some of the most remarkable works of this kind: The great suspension East River Bridge to connect the cities of New York and Brooklyn, more than a mile long, the central opening having a span of nearly 1600 feet; and the St. Louis Bridge, a magnificent bridge crossing the Mississippi by three arches of unequalled width, the centre span being 520 feet clear of masonry.

Signals.[67]—The signalling arrangements form an important part of railway construction. The most common form of signal is the semaphore[68], and at night, coloured lights. A red light signifies danger[72]; a green, caution; and a plain light, that the line is clear.[69] Much care is given to the arrangement and construction of crossings, junctions, &c., with their numerous *switches*[28], or movable rails, used for changing the direction of a train from one line to another. The switches are generally worked directly from the signal-stations, and are so arranged that their points shall not face towards the

57 unterirdisch. 58 Gipfel des Grampian-Gebirges, höchster Berg Grossbritanniens, 1343 Meter hoch. 59 Meeresspiegel. 60 s. Nr. 13. 61 s. Nr. 12. 62 Viaduct. 63 Träger. 64 Pfeiler. 65 Meerenge zwischen Wales und der Insel Anglesea, 21 Kilometer lang, 200 Meter breit; darüber führt die 1846—49 von Stephenson erbaute Britanniabrücke, 461 Meter lang. 66 Ueber den St. Lorenzstrom führt bei Montreal die Victoriabrücke, beinahe 2 englische miles lang, 1854—59 erbaut. *Tamar* Fluss im südwestlichen England. 67 Signal. 68 Semaphor, Flügeltelegraph (gr. σῆμα Zeichen, φέρειν tragen). 69 frei.

advancing traffic. Numerous accidents have been caused by 'facing points'. Many improvements have been lately introduced in signalling, crossings, &c., all with a view to increased safety. The 'block' system has been adopted by the principal railway companies, particularly in the neighbourhood of busy centres of traffic. Under this system each signal station is in telegraphic communication with the nearest signal-stations, both up and down the line, and a train is not allowed to pass any signal station until the train immediately preceding it has started from the next station in advance. Thus the driver may push on without hesitation from point to point; and thereby the traffic is expedited, and at the same time safety increased. The system of *interlocking*[70] has also been extensively introduced. Under this system, the pointsman[71] can only lower one signal—namely, that which corresponds to the line which from the position of the switches, is clear; and before he can alter the position of the switches, he is compelled to return this signal to 'danger'.[72]

Cost of permanent way.[73]—Owing to the obstructions offered by landowners, and their excessive claims for amenity damages, also the opposition of rival companies, the cost of railways was at one time very much greater than it is at present. The expenditure incurred in securing legislative authority to construct railways, was likewise enormous. The parliamentary costs of the Brighton railway averaged £ 4706 per mile; of the Manchester and Birmingham, £ 5190 per mile; and of the Blackwall £ 14,414 per mile! The cost of carrying the Liverpool and Manchester line was £ 27,000. It has been shown that the solicitor's bill for the South-eastern Railway contained 10,000 folios, and amounted to £ 240,000. These few facts, however, afford but a feeble idea of the reckless wastefulness of capital on railway undertakings; it is universally allowed that, under a better policy, not only a much better railway system might have been provided, but a saving effected of at least fifty millions.

The cost of construction varies much. In England, a double line including station-houses, signals, and all other fixed plant, would probably cost, under ordinary circumstances, from £ 15,000 to £ 20,000 per mile. Single lines are made at perhaps a fourth less, but nowhere in the United Kingdom have they been executed so economically as in Scotland. There, some single lines have cost for land and everything not more than about £ 5000 per mile—such economy, however, being greatly due to the fact that the undertakings were promoted and watched over by bodies of land-proprietors deeply interested in restraining expenditure. Of these

[70] s. Nr. 8. [71] Weichensteller. [72] *danger* Gefahr! *stop* halt! *caution* Vorsicht! *go slow* langsam fahren! *all right* Bahn frei! [73] *permanent way* Oberbau.

cheap Scotch lines a good example is offered by the Peebles railway (practically a branch of the North British), extending to $18\frac{3}{4}$ miles, the entire cost of which, land and station-houses included, was about £ 95,000. The cost of rolling stock was additional.

Maintenance[74] *of Way.*—Every railway, great or small, is at a considerable expense in keeping the line in proper working order, for which purpose a staff of officials[75] is required. Besides a general superintendent there is an effective staff of "plate-layers"[76], whose duty it is to watch over the permanent way, to make small repairs, and to report to the superintendent if anything is seriously deranged.

Rolling Stock.[77]—Under this head are comprehended locomotives, carriages, and trucks, for goods and minerals, the whole forming an important part of railway undertakings.

Locomotives.[78]—Locomotives are of several kinds, varied in construction to suit the traffic for which they are designed. They may be classed as *express*, *ordinary*, *passenger*, *goods*, and *tank engines.*[79] In the latter class the *tender*[80] for fuel[81] and water forms an extension of the locomotive; but for the most part the tender is detached, and only connected by *couplings.*[82] Locomotives for ordinary traffic have generally six wheels. In the first two classes, where speed is the principal object, only two, or at most four of the six wheels are *driven*, and these are made of large diameter. There has been a continual tendency to increase the speed, and this has led to an increase in the size of the *driving-wheels*[83], which are in some cases eight feet in diameter. All the wheels of locomotives for heavy traffic are coupled together, so as to utilise the entire weight for adhesion. The smaller class of locomotives have only four wheels. The present price of first-class locomotives—of the largest size in general use—including the tender, varies from £ 3000 to £ 4000. Locomotives of this class weigh in trim from 30 to 40 tons; but there are, of course, much lighter locomotives; while sometimes they are as much as 55 or 56 tons.

Carriages.[84]—There are three distinct kinds of carriages to suit the several classes of passengers. Each first-class carriage[85] consists of three or four distinct *compartments*[86]; but in the other classes, the backs of the seats are in many cases not carried to the roof, leaving the upper part of the carriage open fore and aft.

[74] Unterhaltung; *cost* (oder *expenses*) *of maintenance* Unterhaltungskosten. [75] Beamter. [76] Schienenleger. [77] Rollmaterial, Betriebsmaterial, s. Nr. 6. [78] s. T. II, Nr. 31 fg. [79] *express. engine* Eilzugmaschine, *passenger engine* Personenzugmaschine, *goods engine* Güterzugmaschine, *tank engine* Tendermaschine, *mountain engine* Gebirgslokomotive. [80] Tender. [81] Brennstoff. [82] Kuppelung; *to couple* verkuppeln. [83] *driving-wheel* Treibrad, *trailing-wheel* Tragrad, *leading-wheel* Vorderrad. [84] *carriage* (in Amerika *car*) Wagen, s. Nr. 6. [85] Wagen erster Klasse. [86] Coupé.

At night the carriages are lighted with lamps; on the Metropolitan lines gas is sometimes used. Special *saloon-carriages*[87] are reserved for royalty. The first-class compartments are handsomely fitted up, and in winter are furnished with long-shaped tin vessels of hot water for the feet. Recently, some of the first-class comforts have been acceded to the other classes. The North British Railway Company took the initiative in using *sleeping-carriages*[88] in this country, and the American *Pullman cars*[89] have also been introduced. Many efforts have been made to devise some simple and efficient contrivance by which passengers might, in cases of emergency, summon the guard, but no plan has yet been adopted to any extent. The *'continuous brake'*[90] is an improvement and novelty which has already been successfully tried, and is likely to be soon generally applied. By its use trains can be stopped in a much shorter time and distance than under the present system, and thus the risk of accident is reduced; brakes are fitted to each carriage, and all are simultaneously applied to the wheels. Guard's[91] vans are provided with a look-out box, from which the guard can see along the roofs of all the carriages in the train.

Wagons[92] *and Luggage vans.*[93]—To accommodate its traffic, every railway must be provided with a large stock of *trucks* or wagons for carrying goods, minerals, cattle, timber and other articles. Except for the heaviest traffic, wagons are now very generally fitted with elastic buffers.[94]

Traffic.[95]—The traffic on railways is of two kinds—passengers and goods; with the goods we include minerals, also timber and other bulky articles. The passenger and goods traffic are placed under separate managements. Usually, there are *passenger-trains* and *goods-trains*[96] but *mixed trains* are very common on branch lines.

In every part of the United Kingdom, railway passengers are of three classes—first, second, and third. For the first and second, there are distinct carriages or compartments of carriages; for the third, the carriages are always distinct. The first-class compartments are handsomely fitted up with stuffed cloth seats and backs, are provided with straps for sustaining hats, a netting for um-

[87] Salonwagen. [88] Schlafwagen. [89] Pullmann-Wagen. [90] continuirliche Bremse, s. Nr. 7. [91] Schaffner. [92] *goods wagon* (in Amerika *freight car*) Güterwagen, *truck, (flat car)* offener Güterwagen, *van* oder *covered goods wagon, (box or house car)* gedeckter Güterwagen, *cattle wagon* Viehwagen. [93] Gepäckwagen; *break van* Bremswagen. [94] Buffer. [95] *traffic* Verkehr, *passenger (goods) traffic* Personen- (Güter-) Verkehr, *to open a line for traffic* eine Linie dem Verkehr übergeben, eröffnen. [96] *passenger train* Personenzug, *goods train* Güterzug, *express train* Courierzug, *ordinary train* gewöhnlicher Zug, *mixed train* gemischter Zug, *excursion train* Vergnügungszug, Extrazug, *special train* (bestellter) Extrazug, *mail train* Postzug, *tidal train* Zug, welcher sich nach dem Eintritt der Flut richtet, um die mit bestimmten Schiffen ankommenden Passagiere sofort befördern zu können, *parliamentary train* Personenzug mit allen Klassen und ermässigten Preisen (so genannt, weil eine Parlamentsacte bestimmt, dass auf jeder Eisenbahnlinie täglich wenigstens ein Zug für den Preis von 1 penny pro mile gehen soll), *up-train (down-train)* nach (von) der Hauptstation fahrender Zug.

brellas and small packages, and in winter they are furnished with long-shaped tin vessels of hot water for the feet, which vessels are renewed at certain points in the journey. Though from the fares[97] charged, first-class carriages possess an air of exclusiveness, no more objection is popularly taken to them than to the use of boxes in theatres; and, indeed, they are universally recognized as an advantage, for the reason that by the comparatively high fares exacted for them, the companies are enabled to lower the charges for second and third-class passengers. Special arrangements of each class are now allotted to smokers[98], a custom one may contrast with the special non-smoking carriages common on the continent. The first-class passengers have distinct waiting-rooms at the termini and stations, with generally a waiting-room in addition for ladies; for the second and third class, there is a waiting-room in common. The several waiting-rooms are neatly fitted up, and provided with suitable conveniences, including basins and water for washing the hands—accommodations which contrast favourably with what were furnished to travellers in the old coaching establishments. The waiting-rooms are open all day to the public, and there is seldom any restriction as to going on the platforms. Tickets[99] are sold at a wicket[100] not earlier than a quarter of an hour before the starting of the train.[101] The tickets, marked in consecutive numbers, are stamped with the date on delivery, and, excepting "return tickets", will not answer for any other day. Return tickets at a fare and a half are issued on most lines for the date of issue[102], or from Friday till Monday. On most lines, first and second-class untransferable season tickets are issued for various periods, at a considerable reduction on ordinary fares. To encourage the building of villas at a distance of ten to twenty miles from termini, by which means a traffic may be developed, some companies give a personal ticket free for a number of years corresponding to the valued rental of the villa.

The number of trains run daily depends on the pleasure of the directors. There are *ordinary*, *mail*, and *express*, trains; of this last kind, two usually go each way daily, the fares on which are sometimes higher than by the others.

According to English routine, passengers are allowed to find their way promiscuously to the proper carriages, the only check being a call by the guard to 'show tickets' previous to starting. All passengers are expected to see their luggage labelled[103] for the place of destination, and to point out what belongs to them on arrival.

To enable companies to reckon easily with each other as regards

[97] Fahrpreis, Fahrgeld. [98] Raucher; *smoking compartment* Rauchcoupé. [99] *to take a ticket* ein Billet lösen, *return ticket* Retourbillet, *through-ticket* directes Billet. [100] Schalter. [101] *starting* Abfahren, *stopping* Anhalten, *arrival* Ankunft. [102] Ausgabe. [103] *luggage* Gepäck, *to have one's luggage labelled* sein Gepäck aufgeben (mit einem Zettel mit dem Namen des Bestimmungsortes versehen lassen), *luggage office* Gepäckbureau, *cloak-room* Gepäck-Aufbewahrungszimmer.

intercommunication of traffic in passengers, goods, use of carriages, &c., an institution called the Clearing House [104] has been established in London, to which tickets are transmitted for cross-reckoning and settlement. There is a similar establishment in Dublin.

Cost of Working. [105]—The cost of working railways, including general expenditure, in Great Britain amounts to from 48 to 50 per cent. of the returns from traffic. The remainder forms the divisible profit to pay—1st, the interest on debentures; and 2d, the dividend to shareholders. Of these shareholders, some, as defined by statute, have a preference claim of 5 per cent. per annum, what is left over being divisible among the ordinary or original shareholders. In the general expenditure of railway companies is included the outlay for passenger-tax, also police, poor, and parish-rates.

According to a return made by railway companies to the Board of Trade in 1871, the cost of running trains was on an average 30·33d. per mile, or about £ 13 for 100 miles. Lowness of fares can be secured only by a large and well-sustained traffic; and the main reason why fares are much higher than they seemingly might be, is the frequent insufficiency of the number of passengers compared with the accommodation provided for them. A striking exemplification of the possibility of conveying large numbers at very low fares is afforded in the case of "excursion trains" [96] in which sometimes 1000 individuals are taken 50 or more miles, and brought back the same day for one or two shillings each.

Statistics.—A return issued by the Board of Trade gives the following statistics for the United Kingdom for the year ending December 31, 1876: Number of miles open, 16,872; number of passengers, 538,287,295; miles travelled by passenger-trains, 215,711,739; receipts from passengers, £ 23,057,731; total receipts from all services, £ 62,215,775; total working expenses including maintenance of way, locomotive power, repairs and renewals of carriages, etc., £ 33,535,509; net balance of receipts over expenditure, £ 28,680,266; vehicles of all sorts employed, 464,527; authorized capital, by shares, £ 540,095,705, by loans, £ 192,706,822; total paid up on shares and debenture loans, £ 658,214,776.

Foreign Railways.—The first foreign country that availed itself of railway locomotion was the small kingdom of Belgium, where a number of lines in connection with each other were constructed between 1834 and 1836, and in about ten years afterwards the group was nearly completed in a well-devised and comprehensive scheme. At the beginning of 1864, the number of miles in operation in Belgium was 1073, about eight-tenths of which were the work of government; and we are told, on good authority, that the

[104] Abrechnungshaus. [105] Betriebskosten.

cost has been on an average £ 18,000 per mile, but this seems to include expenses on rolling stock.

From Belgium railways spread to France, where they were laid down on a plan prescribed by the government, which offered special encouragement to capitalists. The method adopted was to give the land and make the bridges, but besides these heavy items of expenditure, the government was in a number of instances at the cost of the entire permanent way. So far favoured, the promoters, who formed a company, had only to find capital to work and maintain the line. The government, however, relinquished the property only on the footing of a lease for such a number of years as a company was disposed to be satisfied with. Tenders were ordinarily taken from competing bodies of promoters; in this manner the "concession", or right of tenancy, has been adjusted at from 50 to 99 years; at the end of the prescribed periods the lines will fall into the hands of the government. Latterly, the French system has outgrown this kind of tutelage, and there is a disposition in companies to act on an independent footing; the state, however, has secured a very general right of property in the existing lines, whether by the method of assistance originally fallen upon, or by giving large subventions of money, on the plan of receiving a share of profits after a certain dividend has been reached. By means of these subventions, as well as a species of guaranteed monopoly of traffic, the profits to share-holders in some French lines reach from 10 to 12 per cent. On one or other of the various plans of government helping companies, and preventing ruinous competition, nearly the whole railway system of continental Europe, Asia and Africa is etablished; and in a large number of the foreign railway undertakings everywhere much British capital is invested. The principal continental railways, particularly in France and Belgium, are double lines, and under good management; but the rate of transit is generally slower than in England, and the formalities as to taking tickets and being allowed to enter the trains are exceedingly troublesome.

Various continental lines have been constructed by English contractors, who employed English navvies for the purpose along with the usual apparatus of trucks, wheelbarrows, &c. In Italy, however, as lately as 1862, we observed that the work of construction was performed in a tedious and laborious manner by women and girls, who carried the earth in baskets on their heads, under the superintendence of taskmasters with whips—a sorrowful spectacle, and the more surprising as being in a country noted for its advancement in practical engineering.

In Canada, Nova Scotia and Australia railways have been successfully established; but in no British dependency has the railway system been latterly pushed forward with such activity or likelihood of advantage as in India, where, at the end of 1863, lines had been

sanctioned which would cost £ 60,000,000 and about 1000 miles were opened for traffic. The undertakings have been materially assisted by government, by giving the land to the companies, by subvention in proportion to the actual outlay, and in some instances by guarantees of a minimum dividend of 5 per cent. to shareholders. In the execution of railways in India, the mercantile community of Great Britain have taken a deep interest, for hitherto the difficulty and cost of transit of cotton and other bulky articles of export from that vast dependency has proved a serious detriment to commercial intercourse.

Railways in the United States date from 1730, when a short line was made in Massachusetts. Since that year, the progress of railways has kept pace with, if not exceeded, that of Great Britain.[106] All the American lines are constructed and worked by private companies, but in other respects they differ materially from similar undertakings in England. A few peculiarities of the American routine may be noted. The cost of procuring legislative authority to make the lines has usually been very small; the lines are mostly single, and the land for them has often been either given for nothing, or for a comparatively trifling consideration; the lines have generally no fences, and they go through populous towns along the open streets without restriction or fear of the consequences; the only care taken against accidents is for the driver to ring a bell, and it is usual to put up boards with the inscription: "Look out for the Locomotive when the bell rings"; tickets are sold by the guard or at offices throughout a town without fixing a date, just as ordinary articles are sold at a shop; the waiting-rooms are generally of a poor description; as regards passengers, all varieties (negroes excepted) travel in one carriage; and lastly, there is a marked deficiency of porters, station-keepers, and other officials either to give information or render assistance to passengers.

The seats in the "cars", as they are termed, are arranged in rows, with a passage up the middle for the conductor, who, by means of a small platform at each end, can step from carriage to carriage, and perambulate the train at pleasure, which he is constantly doing in performance of his ticket-selling and ticket-taking duty. The wheels being attached to a swivel or *bogie* framework,

[106] The total length of the railways in operation (*in operation* im Betrieb, *in progress* im Bau) in the United States on the 1st of January, 1877, was 76,640 miles (January, 1878, about 80,000 miles), being an average of one mile of railway for every 600 inhabitants. The greatest milage is in Illinois, reaching 6,980; the smallest in Rhode Island, 182, and in Washington Territory, 110. The State of Massachusetts has one mile of railroad to 4.86 miles of territory, this ratio being the greatest in the country. The longest road in operation is the Chicago & Northwestern, extending 1,500 miles; the shortest, the Little Saw-Mill Run Road in Pennsylvania, which is but three miles in length. The total capital of railways in the country is $ 6,000,000,000, or an average of $ 100,000 per mile. The earnings for the year 1872 amounted to $ 454,969,000, or $ 7,500 per mile. The largest net earnings recorded as made on any road were gained by the New York Central & Hudson River, $ 8,260,827. THURSTON.

the cars can turn round corners with the ease and security of a gentleman's carriage; this being the most ingenious of the American mechanical arrangements. Altogether, the railway system of the United States can in no shape be brought into comparison with that of the United Kingdom, for the two things are constituted on very different principles. The chief desire in America has been to open up the country at all hazards to railway communication, leaving improvements to be effected afterwards by the wealth which that communication is almost certain to create. On the contrary, in Great Britain and Ireland, there has been no pervading aim of this kind; every railway scheme has been legislated for and loaded with expenses as if it were a matter of indifference to the nation whether such projects should be carried out or not; and, as is well known, the comfort and convenience of passengers has, on the whole, at whatever cost, been a matter of primary concern to the companies.

CHAMBERS'S *Encyclopædia*.

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5. REMARKS UPON RAILS.*

A GOOD *rail*[1] must be able to act as a girder[2] or support between the sleepers[3], and as a lateral guide for the wheels. It must possess a top surface of sufficient size and hardness to withstand the action of the rolling weights, and a bottom surface which shall afford the requisite amount of bearing upon the sleeper. One square inch of rail section weighs 10 pounds per running yard, very nearly, which, at $ 60 a ton for iron rails, would amount to $ 1000 per mile of track[4]; whence the need of rolling the rail to that form which shall give the required strength with the least weight, may plainly be seen. The stiffness of rectangular beams is as the cube of depth. If the rails deflect, the result is the same as if the wheels were rolling up a grade.[5] Mr. Barlow found the deflection of a 50 pounds rail $3\frac{5}{8}$ inches deep, the bearing being 3 feet, under a load of 5 tons at rest, to be equal to a grade of 25 feet per mile. At high speeds it would be more. If from settling of the track any one sleeper does not bear upon the ground, this deflection will, of course, be greater, corresponding to a steeper grade. The importance of depth in a rail is now fully seen, the old heights of $3\frac{1}{2}$ and $3\frac{3}{4}$ inches having given place to 4, $4\frac{1}{2}$, and 5 inches. The old idea that the head[6] needed to be supported from the stem by a long

[1] *Rail*, s. Nr. 4, 42. [2] Träger. [3] Schwelle, s. Nr. 4, 50. [4] Gleis. [5] Steigung, s. Nr. 4, 34. [6] *head* Kopf, *stem* oder *web* Steg, *foot* Fuss.

* S. *Technical Vocabulary*, S. 172—174.

slope is now seen to be erroneous. The head may be as little as an inch deep, connected with the stem by a short curve [7], thus allowing room for a good fish plate. [8] The edge of a rail well made, and of good material, never splits off. From 60 to 65 pounds per yard appears to be sufficiently heavy for any service, provided the rail is well proportioned. The form of rail in general use in America, and indeed everywhere, except in Great Britain, is the flat-footed, or American rail. [9]

Inclination [10] *of Rails.*—As the tread [11] of the wheel is conical, the top of the rail must be inclined to fit this cone, otherwise, the wear will come upon the inner edge of the rail only. This may be done in two ways: by placing the rail base level, and inclining the vertical axis of the cross section [12] of the rail, and making the tread square with that axis; or by making the rail section true, and inclining the base, either by cutting the tie [13], or by using a block like that of Mr. Whitman's, let in at the proper angle. The amount of cant or bevel to be given to the rail depends upon the cone of the wheel, and this latter depends upon the gauge [14] of the track and the radius of curvature. [7]

Life [15] *of Rails.*—The duration or life of rails depends upon the quality of the iron of which they are made, and upon the amount and speed of the traffic [16] passing over them. The rails first made in England were rolled from best Nr. 1 cold blast mine iron [17], run out in a finery fire [18], puddled, shingled [19], rolled [20] into bars, which were cut, piled [21], heated, and hammered into blooms, and these were reheated [17] and rolled into rails. The result was a material such as is rarely seen upon our railways at the present time. The old 45 pounds Reading rail bore an immense traffic for 20 years. The iron at first used upon English roads in many cases withstood from 15 to 20 years of wear under an enormous traffic. With the material now put into railway tracks, good iron will last 8 years under an average traffic; but with the material commonly employed, from 3 to 6 years is all that can be counted upon for roads doing a good amount of work; and the life of iron upon the great routes is in many cases less than this. Mr. Price Williams states in a paper read before the London Inst. Civ. Eng., that the average life of the best quality of iron rails has been found to be, in round numbers, 15,000,000 tons, or 100,000 trains of 150 tons each. That where from 12,000,000 to 15,000,000 tons of moderately fast traffic will wear out an iron rail, 38,000,000 tons of slow traffic are required to do the same. That the wear is greatest upon grades falling in the direction of the traffic. A mixed traffic of 62,399

[7] s. Nr. 4, 33. [8] Lasche; s. Nr. 4, 51. [9] Fuss- oder breitbasige Schiene. [10] Neigung. [11] Lauffläche, s. Nr. 6, 49. [12] Querschnitt, Querprofil; *rail section* Schienenprofil. [13] *tie* in Amerika = *sleeper*. [14] Spurweite, s. Nr. 4, 40. [15] Dauer. [16] Verkehr. [17] s. Teil II, Nr. 2 und I, Nr. 28. [18] Feineisenfeuer. [19] zängen. [20] walzen. [21] packetiren; *rail pile* Schienenpacket. [22] sich verhalten wie.

trains, or of 12,000,000 tons, very nearly, wore out the best rails on a 40 feet descending grade in $7\frac{1}{4}$ years, while the same description of rails upon a level, under a very heavy traffic, required 203,122 trains, or 38,000,000 tons, very nearly, to wear them out. For equal amounts of traffic, the wear of rails is assumed to be as[22] the square of the speed.

Steel Rails.[23]—With regard to the life of steel rails, everything here again depends upon the quality of the metal. A pair of 21 feet Bessemer steel rails, upon the London and North Western Railway, outlasted 16 faces of iron rails, being evenly worn to a depth of a little over $\frac{1}{4}$ of an inch; having in about 3 years sustained the traffic of upwards of 9,000,000 engines and cars, or about 95,000,000 tons.

Whether it will be the most economical to employ rails of iron or steel, or of iron with a steel head, depends upon the amount of traffic which is to pass over the track, and the facility for obtaining the different materials. The interest upon the first cost of rails is an important element in this question. It is also to be considered that the steel rail deflects much less under a given load, and thus reduces the resistance to traction. Finally, the employment of steel rails, by giving a smoother and better track, reduces the cost of repairs of the rolling stock[24], as the track and machinery act upon each other, and thus adds to the safety of travelling.

Specification for Rails.—The German Railway Union specifies the following in regard to iron rails:—"The rail top must consist of hard granular[25] iron to a depth of at least $\frac{3}{4}$ of an inch in the finished rail, and the rail base of soft fibrous[26] iron not less than $\frac{9}{16}$ inch thick. The bars laid between the top and bottom slabs must be of such quality as to weld well amongst each other, and to effect a gradual transition of the degree of welding heat[27], which is lowest in the top slab and highest in the bottom slab. All mill bars[28] or flats, which are used in piling[21], must be rolled from hammered blooms.[29] Top slabs, whether made from piles or solid blooms, must be hammered before rolling. The rail piles must be hammered at full welding heat under a steam hammer[30] not less than five tons falling weight, then reheated and rolled."

Tests for Rails.[31]—The tests for iron rails adopted by the German Railway Union are as follows: The rail being placed on solid supports, 3.28 feet apart, is cut $\frac{1}{8}$ inch in the head, and broken bottom up. It is then cut $\frac{1}{8}$ inch in the base, and broken head up. The surface of fracture[32] broken either way must show perfectly granular heads, fibrous flanges, and no open welds. This test

[23] Stahlschiene; *steel-headed rail* Stahlkopfschiene. [24] Rollmaterial. [25] körnig. [26] sehnig. [27] Schweisshitze. [28] Rohschiene. [29] Luppe. [30] s. Teil II, Nr. 15. [31] Schienenprobe. [32] Bruch.

determines the quality of the material, and also, to some extent, the workmanship. The drop test lets a ram of half a ton fall 11.48 feet upon the middle of the rail, placed on supports, 3.28 feet apart. This test shows the endurance of the rail against sudden shocks, though it does not show the quality of the material, as the fibrous iron, broken by so sudden a shock, may appear granular. To test the limit of elasticity the rail is placed upon solid supports, 3.28 feet apart, and first $12\frac{1}{2}$ tons are placed on the centre of the rail, which, after 5 minutes' pressure, must not show permanent set[33]; second, 25 tons, applied in the same way for 5 minutes, must not break the rail.

George L. Vose, *Manual for Railroad Engineers.*

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6. ROLLING STOCK.*

Passenger rolling stock consists of first, second, third class, and composite carriages, luggage, and break vans[1], horse-boxes, carriage trucks, and some special descriptions of vehicles which run with passenger trains[2], such as invalid and saloon carriages, bullion trucks, post-office vans, and tenders. Goods rolling stock consists of waggons[1] of various shapes and sizes, covered and uncovered, for the conveyance of general merchandise, waggons for minerals or ballast, trucks for stone, trucks for timber, break vans, and special waggons designed for particular localities and suitable to particular purposes, such as the conveyance of salt, gunpowder, fresh meat, milk, &c., &c.

The details of the special classes of rolling stock, whether for passengers or goods, will not be referred to, but the construction of the ordinary carriages and waggons in every day use will be briefly discussed. The leading features of the constructional parts are much the same in all cases, and are not materially affected by the modifications by which the stock is adapted to special purposes.

Carriages were formerly seldom or never made with more than three compartments[3], and those compartments were much smaller than those of modern carriages. The internal dimensions of the different descriptions of carriages now adopted as compared with those of 1845 will be referred to below; but, to take one instance, an old first-class compartment was only 5 ft. 5 ins. between the

[33] s. Teil II, Nr. 1, 44.
[1] s. Nr. 4, 84—93. [2] s. Nr. 4, 96. [3] Coupé.
* S. *Technical Vocabulary*, S. 160—161 und 176—177.

partitions, whereas now it is usually about 6 ft. 3½ ins.; and, whereas formerly a full-sized carriage had three compartments, and was about 20 feet long (including the buffers), it has now four or five compartments, and is from 29 to 36 feet long.

Comparison of length, width, and weight of carriages in 1875 *and* 1845, *and percentage of paying load in total weight.*

	Length of body outside over buffers.	Width of body outside.	Total weight of empty vehicle.	No. of passengers.	Total weight of vehicle fully loaded.	Percentage of paying load to total weight of fully loaded vehicle. Total weight of fully loaded vehicle = 100.
	ft. ins.	ft. ins.	tons cwt.	No.	tons cwt.	per cent.
First Class 1875	27 0	8 4	9 19	32	12 2	17·7
First Class *1845*	*16 9*	*7 0*	*4 4*	*18*	*5 8*	*22·3*
Second Class 1875	24 0	8 4	7 16	40	10 9	25·6
Second Class *1845*	*19 0*	*6 6*	*4 2*	*32*	*6 5*	*34·3*
Third Class 1875	27 0	8 4	8 7	50	11 14	28·7
Third Class *1845*	*17 6*	*8 2*	*4 4*	*40*	*6 17*	*39·0*

The width and height of carriages have also been increased, in order to meet the requirements of the public, and thus the dead weight[4] of carriages has increased relatively to the paying load[5] which they carry, as is shown by the accompanying tables. This matter is of much importance with passenger carriages, but it is of much greater consequence in the case of goods and mineral waggons, as the rates are low and the margin of profit is small in such traffic.[6] The tables give an idea of the weight of the rolling stock of a first-class railway at the present time and 30 years ago, the ratio[7] of the paying load to the total weight of the fully loaded vehicle is in each case given in the last column.

The several parts forming a *carriage* or *waggon* may be conveniently dealt with under two heads; first, the *undercarriage*[8]; and secondly, the upper part or *body*[9] of the carriages and waggons.

The *undercarriage* consists of:—

1. The *underframe*[10], which is the framework by which the body of the vehicle is supported, and by which the weight is transferred to the wheels.

2. The *bearing springs*[23], or those between the underframe and the wheels.

3. The *buffer springs*[30] and the drawbar springs.

[4] totes Gewicht. [5] Nutzlast; *total load* Gesammt-, Bruttobelastung. [6] Verkehr. [7] Verhältniss. [8] Unterwagen. [9] Wagenkasten. [10] *frame* Gestell, Rahmen, *underframe* Untergestell.

4. The *axles* and *wheels.*[44]

5. The *axle-boxes* and *bearings.*[58]

Underframes.[10]—In the case of carriages the construction of the *underframes*, and the sizes of the timbers used, assuming that the lengths of the carriages are the same, are generally similar for all classes of carriages. In the case of waggons, if the sizes of the trucks[8] are the same, or approximately the same, and the loads to be carried by them similar, no essential difference will be found in the underframe, whatever may be the purposes for which the trucks are destined.

Comparison of weight of waggons in 1875 *and* 1845, *and percentage of paying load in total weight.*

Class of waggon.		Total weight of empty vehicle.		To carry.	Total weight of fully loaded vehicle.		Percentage of paying load. Total weight of fully loaded vehicle = 100·0.
		tons	cwt.	tons	tons	cwt.	
Covered Goods	1875	5	9	6	11	9	52·4
	1845	*3*	*12*	*6*	*9*	*12*	*62·5*
Open Goods	1875	5	5	8	13	5	60·4
	1845	*3*	*10*	*5*	*8*	*10*	*58·8*
Coal	1875	4	9	8	12	9	64·26
	1875	4	5	8	12	5	65·3
	1875	3	19	6	9	19	60·3
	1845	*3*	*6*	*6*	*9*	*6*	*64·5*

Modern carriages are made long in order to ensure easy running, and consequently the underframes have to be made of considerable strength relatively to their paying loads, to resist the strains[11] due to the extra length of carriages as compared with the shorter length adopted for waggons.

Fig. 3 shows the under carriage of a modern first-class carriage with six wheels.

An underframe consists of the following parts, which are distinguished on the sketches by letters corresponding to those in the following list of the timbers composing the frame:—

a. Soles[12], which are the side timbers, extending longitudinally from end to end of the frame.

b. Head stocks[13] or end timbers, which unite the soles at their ends, and with them form the outside timbers of the frame.

[11] s. Teil II, Nr. 1. [12] Langschwelle. [13] Kopfschwelle.

c. Cross bars[14] or transverse timbers, parallel to the head stocks.

d. Diagonals[15] which, as their name implies, are placed in a diagonal direction, between the head stock and the centre of the

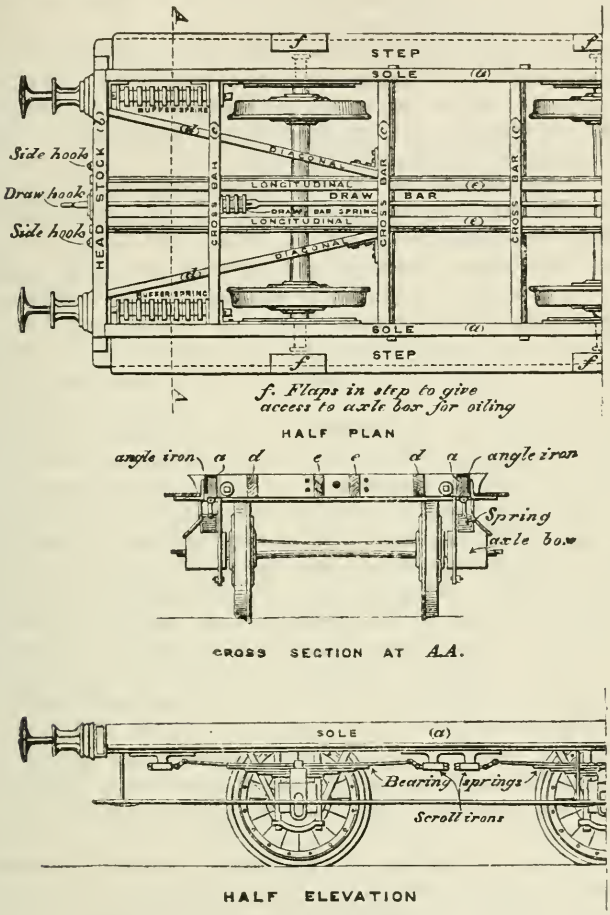

Fig. 3.

frame, so as to convey the strains which come on the head stock to the framing generally, and to prevent any alteration in the shape of the framing.

e. The longitudinals, which are timbers placed parallel to the

[14] Querschwelle. [15] Strebe.

soles to strengthen the head stocks and cross bars, and afford intermediate support between the soles for the floor of the body.

The soles have to act as girders[16] to carry the weight of the body from wheel to wheel, and in the case of long carriages the soles are often made with flat plates of iron or steel, or with deep angle irons[17], extending in most cases from end to end of the frame, and firmly bolted[18] to the timber. The junctions of all the timbers are made with strong iron knees and bolts. The greatest care is given to make the frame extremely strong against the various strains lengthways, crossways, and diagonally, to which a railway vehicle[19] is constantly exposed.

No expense should be spared in securing sound seasoned[20] timber for the whole of the underframe, as the cost of the labour to construct the frame is greatly in excess of the value of the raw material. The timber generally used for underframes is either teak or oak, both of which are very suitable for the purpose. The underframe should be protected from the weather and from water soaking into the joints[21] between the timbers in every practicable way, by paint or varnish[22], and by coverings over the joints.

Springs.—The *bearing springs*[23] are interposed between the frame and the axle-box[24], so that the carriage may ride easily, and that sudden blows or impulses given to the wheels resulting from inequalities of the road or similar causes may not be transmitted to the body of the carriage. The bearing springs of carriages and waggons are made of steel plates[25], about $3\frac{1}{2}$ inches wide and $\frac{3}{8}$ inch thick. The spring plates are held together at their centre by a band[26] or link of wrought-iron, into which the plates are firmly secured, or by a bolt passing through all the plates. The band or link is either bolted down on to the top of the axle-box, or merely fits into a mortice[27] in the top of the axle-box, in which it is held by the weight of the carriage, while the situation of the bottom of the band in the mortice prevents any lateral motion taking place between the spring and the axle-box. The ends of the spring are attached to the sole by brackets, which are called "scroll irons".

Buffers[28] *and Draw-bars.*[29]—The *buffer springs*[30] for carriages were formerly almost universally, and are still, in many cases, made, like bearing springs, of flat steel plates, fixed horizontally at the centre of the frame between the two centre cross bars. In such cases there are two springs to each carriage, placed back to back, one to receive the thrust of one pair of buffers, and the other to

[16] Träger. [17] Winkeleisen. [18] *bolt* Bolzen, *screw-bolt* Schraubenbolzen. [19] Eisenbahn-Fahrzeug, -Fuhrwerk. [20] s. Teil II, Nr. 3. [21] Fuge, Stoss. [22] Firniss. [23] Tragfeder. [24] Achsbüchse. [25] Stahlblatt; *plate spring* Blattfeder. [26] Federbügel. [27] Zapfenloch. [28] Buffer. [29] Zugstange. [30] Bufferfeder.

receive the thrust of the other pair of buffers. The buffer rods[31] rest against the ends of the springs, which can turn to a slight extent on their centres, and so if one buffer be pushed in, the opposite buffer is pressed outwards by the opposite end of the spring. The draw-bar of the carriage, which is a bar in prolongation of the hook[32] by which a carriage is attached to its neighbour, is generally made fast to the centre of the buffer spring, which thus yields slightly to the tractive force exerted on the hook of the draw-bar.

Carriages are attached one to the other by what is called a *coupling*[33], which consists of two elongated links[34] of wrought iron, united by a right and left handed screw[35], which can be turned round so as to lengthen or shorten the coupling. Attached to the screw is a pendent lever[36] with a weight on its end to assist in its being turned round, and when carriages are to be coupled together, the screw should be turned round sufficiently often to bring a good strain on the buffer springs.

The long plate springs across the carriage are, however, cumbrous, and expensive, and are being to a great extent superseded by india-rubber springs[37], which are formed of a number of discs[38] of vulcanised[39] india-rubber, enclosed in iron rings, and placed between thin discs of iron. The india-rubber discs are from $2\frac{1}{2}$ to 3 ins. thick, and from 6 to 8 discs form a buffer-spring of a modern carriage. The buffer as it is pushed inwards by the pull of the coupling compresses the india-rubber, which resumes its original dimensions when released from pressure.

Chains, called *sidechains*[40], are fixed to the head-stocks on each side of the hook of the draw-bar. These chains are attached together by the hooks at their ends, and are only intended to come into action if any coupling or draw-bar break. In the case of waggon stock the buffer and draw-bar springs are often made with *volute springs*[41], which are formed of steel plates bent into a helical form.

Goods trucks are, as a rule, not coupled tightly together by a screw coupling, but are merely attached by chains which have a considerable amount of slack when the buffers are in contact. This arrangement is adopted partly for convenience of coupling and uncoupling, but more for the increased facility which loose coupling affords for starting[42] a heavy train. With loose couplings the engine starts each truck separately, and, to start the afterpart of the train, the power of the engine is assisted by the momentum

[31] Bufferstange. [32] *draw-hook* Zughaken. [33] Kuppelung; *screw-coupling* Schraubenkuppelung, *coupling-chain* Kuppelkette, *to couple* kuppeln. [34] Kettenglied, Bügel. [35] s. Teil II, Nr. 5. [36] Hebel. [37] Gummifeder. [38] Scheibe. [39] vulcanisirt. [40] Notkette. [41] Schneckenfeder, Baillie feder. [42] in Bewegung setzen, anfahren.

of the engine and of all the trucks which have already started and have gathered way.

Some carriages are made without any spring buffers, and are coupled together tightly at the centre of the head-stock without any slack in the draw-bars. This arrangement is common in the United States and in other countries where the long American carriages are adopted.

Wheels and Axles.—The *wheels* and *axles* of rolling stock are very much of one general type throughout this country; but there are considerable differences in detail. One important point of similarity consists in both wheels being fixed to the axle, so that the wheel and axle revolve together.

A *wheel* of an ordinary roadway vehicle[43] consists of the following parts:—The *nave* or *boss*[44], the *spokes*[45], the *felloes*[46] or outside ring into which the spokes fit, the *tire*[47] which is put on around the felloes. The nave, spokes, and felloes form the framework of a roadway wheel, and the purpose of the tire is to hold the felloes and the rest of the framework together, and at the same time to protect the felloes from being worn away by attrition on the road. The construction of a *railway wheel* differs from that of a roadway wheel in the tire of a railway wheel combining the chief functions of the felloes and the tire of a roadway wheel, the tire resembling a continuous felloe rather than the tire of a roadway wheel.

The technical names for the parts of a railway wheel are as follows:—The *boss*[44] is the centre portion into which the axle fits, the *tire*[48] is the outside ring, the *body* is the part between the boss and the tire. The *tread*[49] of the wheel is the part which runs on the rails; the *flange*[50] is the narrow part of larger diameter than the tread, which consequently extends downwards below the top of the rails; the *throat* is that part of the tire at which the flange joins the tread; and the *back* of the wheel is the portion of the tire which, when the wheel is in its position on the axle, is nearest to the opposite tire. Thus the distance between the backs of opposite wheels is the shortest transverse distance between any part of the flanges of opposite wheels, and the distance between the throats is the longest distance between any part of the flanges. The latter measurement is of great importance as respects the gauge[51] of the permanent way[52]; the measurement between the backs of wheels is of equal importance in connection with the position of guard rails, check rails, and crossings.[53]

The boss of a railway wheel is generally made of cast-iron, but occasionally of wrought-iron, and is accurately bored to fit the axle.

[43] Strassenfuhrwerk. [44] Nabe. [45] Speiche. [46] Felge. [47] Reifen. [48] Bandage, Radreif. [49] Lauffläche. [50] Flantsch, Spurkranz. [51] Spurweite. [52] Oberbau. [53] *crossing* Kreuzung, *check rail* Backenschiene, Hornschiene, *guard rail* Zwangschiene.

The wheel is secured to the axle either by means of a key[54], or the key is dispensed with, and the boss of the wheel being bored smaller than the diameter of the axle, the wheel is slightly heated and forced on to the axle by hydraulic pressure[55], the fit being such that the wheel, when it is cold and shrunk, remains tightly fixed in its place.

The bodies of railway wheels are in this country usually made either of wrought-iron in the form of spokes, or of solid wood. Spokes are objectionable in a railway wheel from the unnecessary resistance occasioned by their beating the air in their rapid revolution, and from their consequently raising the dust from the ballast, which finds its way into and damages the axle bearings. Solid wheels, which are free from these objections, and which possess the further advantage that they support the tire continuously, are therefore generally adopted for all high-class carriage and waggon stock. The solid bodies of wheels are made of various materials, but that usually adopted is wood, well seasoned, and put together in sectors of a circle, with the grain as far as possible radial.

Wheels have been made extensively in America and in some other countries of cast-iron throughout, and the part forming the tire is in that case chilled[56], so as to harden its surface, and the wheels are very carefully annealed.[57]

Axle Boxes and Bearings.—The *axle-box*[58] and *bearings*[59] are very important parts of rolling stock, as upon their form and treatment the wellbeing of the stock, the tractive[60] force required to propel a train, and the comfort of the passengers, greatly depend. The bodies of railway rolling stock are supported on the *journals*[61] of the axle outside the wheels, and are therefore different to the bodies of roadway vehicles, which are always supported within the wheels. The springs rest on the top of the axle-box, and the axle-box rests on a *brass*[62] bearing which is placed on the journal. The great points aimed at in a good axle-box are, good *lubrication*[63] of the brass bearing, and the exclusion of dirt and dust. Without constant good lubrication the brasses get heated, and the surfaces of the brasses or of the journals are destroyed. The lubricants[65] used are either specially prepared grease[64] or oil of different kinds. The former was the original lubricant adopted on railways, and is still much employed, though oil has by this time been proved to be more efficient.

The axle-box is kept in its position relative to the underframe of the carriage, by the springs and by the *axle-guards* or *horn-*

[54] Keil. [55] s. Teil I, Nr. 3. [56] *to chill* abschrecken, in Schalen giessen, *chilled wheel* Schalengussrad. [57] anlassen. [58] Achsbüchse. [59] Lager, s. Teil II, Nr. 4. [60] Zugkraft. [61] Schenkel. [62] Messing; Lager(futter). [63] Schmieren. [64] Schmiere; *grease-box* Schmierbüchse. [65] Schmiermittel.

plates[66] which are wrought-iron or steel plates bolted to the soles, and projecting downwards below the underframe, in grooves in the sides of the axle-box. The axle-guard projects below the bottom of the axle-box, and a longitudinal bar is bolted to the lower ends of the guard, to connect together the guards on the same side of the carriage. The upper ends of the axle-guards are spread out in various ways so as to take hold of a large part of the sole to which they are bolted.

Carriage Bodies.—The *bodies*[9] of the carriages and waggons in use in this country, which rest on the underframes described above, cannot be treated with any minute examination within the limits of this chapter. The mode of fitting-up the carriages of the different classes should aim at giving the most comfortable seat possible with the expenditure permitted for the description of carriage. The partitions of some carriages, particularly those of second and third class on short traffic lines, are often not carried up to the ceiling. Where this is the case the partitions should be carried up beyond the level of the head of a man when sitting down, so as to avoid draughts from open windows in adjoining compartments.[3]

Comparison of length, width, height, &c., of compartment of passenger stock in 1875 *and* 1845.

		Length of compartment between partitions.	Width of compartment.	Height of compartment at centre.	Depth of seat from front to back.	Width of seat for each person.	Height of doorway.	Width of doorway.
		ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.
First Class	1875	6 $3\frac{1}{2}$	6 9	7 0	1 7	2 2	6 0	2 1
	1845	*5 5*	*6 6*	*5 6*	*1 $5\frac{1}{2}$*	*2 1*	*4 $10\frac{3}{4}$*	*1 10*
Second Class	1875	5 10	7 9	7 0	1 5	6 $6\frac{1}{2}$	6 0	2 1
	1845	*4 7*	*6 0*	*5 6*	*1 $2\frac{1}{2}$*	*1 6*	*4 10*	*1 7*
Third Class	1875	5 $3\frac{1}{2}$	7 9	7 0	1 4	1 $6\frac{1}{2}$	6 0	2 1
	1845	*4 2*	*6 10*	*5 9*	*1 $3\frac{1}{2}$*	*1 $4\frac{1}{2}$*	*5 $2\frac{1}{2}$*	*1 7*

The lighting of carriages in this country at night is by no means satisfactory, except where gas is used, but there can be no

[66] Achsenhalter.

good reason why with a little care to the subject a light good enough to read by with comfort should not be given in all carriages. The arrangements with regard to foot-warmers, except on some of the lines from London to the North, are not worthy of the companies. Probably, if the number of portable hot water-tins required is a serious difficulty, the carriages could be warmed from the engine without much trouble. In respect of lighting and warming the carriages English railways contrast unfavourably with those of other countries.

The sizes of some of the compartments of carriages now used in this country are given above, and in a second column are given the sizes of similar compartments thirty years ago, by which an idea will be given of how much our rolling stock has improved in size and comfort.

The woods used for the bodies of carriages are usually mahogany, oak, and teak, for external work, and deal for the internal partitions. The roofs are generally covered with boarding, over which painted canvas is laid. It is of the greatest importance, in order to prevent the bodies from being affected by the weather, that all external parts should be protected by paint or varnish.

It is impossible to enter minutely into the several details of the fittings of the different classes of carriages, such as the kinds of windows, doors, handles, steps, lamps, and other fittings, as any attempt to deal with such matters would require a space far beyond that now available. The same remark applies to the mode of constructing the upper parts of waggon stock. The great point aimed at is that the waggons should be suitable to the nature of the traffic for which they are destined, and to the places to which they have to go. Thus there are low-sided, high-sided, covered, and uncovered trucks; some, such as coal or ironstone waggons, have trap-doors in their bottoms by which their load is discharged downwards; all trucks, as a rule, discharge at their sides if required, and some at their ends as well. The wood generally employed for the upper work of trucks is oak and deal, and in the best waggons all edges and angles are protected and strengthened by wrought iron. The wear and tear of waggon stock is very great, and it is wise to avoid spending too much on the upper work of the waggons, but to make the underframes very strong, so that they may receive new bodies when required.

BARRY, *Railway Appliances.*

7. BRAKES.

The ordinary method of stopping a train is by *brakes*[1] applied by hand to each set of wheels. This is done by the brakeman[2], who stands between the cars, first to the front of one car and then to the rear of the adjacent one. The retarding force is thus applied irregularly, and without any system, to the discomfort of passengers, and often to the damage of the cars. A correct system should apply a sufficient power, gradually and uniformly, to the whole train. Many plans for retarding trains have been contrived, some of them self-acting[3], others applied at the engine. The Creamer Brake, by which the blocks[4] are forced upon the wheels by strong springs[5], and when not wanted, are forcibly drawn away and locked, is a simple and effective contrivance. The Loughbridge Brake is worked from the back driving wheel[6] of the engine, the flange of which runs into the groove of a pulley[7], which has connection, by means of a chain, with the brakes under the cars. The ordinary hand brakes are connected with the same apparatus, the two systems, however, being distinct in operation.

The Westinghouse Atmospheric Brake[8] consists of an upright direct-acting air pump[9], placed on the right hand side of the engine, between the driving wheels, taking its steam from the boiler[10], and pumping air into a cylindrical reservoir placed beneath the foot-board.[11] The pump is entirely self-acting, and is, in fact, a medium between the pressure of steam in the boiler and the pressure of air in the reservoir. When the boiler pressure rises, the pump works more actively, until the pressure of the air in the reservoir rises to correspond; or, if air is drawn from the reservoir to apply the brake, the pump at once begins to work more vigorously, without attention from the engineer, to make up the deficiency of pressure in the reservoir. Under each car is placed a small cylinder, the piston[12] of which acts directly on the lever[4] commonly used for the hand brake, but in no way interfering with braking by hand. The condensed steam is carried to these cylinders by a $\frac{3}{4}$ inch gas pipe[13], running beneath the cars the entire length of the train, a connection being made at the shackling of the cars by rubber hose[14], so coupled[15] that when the parts are united the air passes freely along; but should the train be broken at a coupling, a valve[16] closes, and prevents the escape of air, the brakes remaining effective. By this arrangement the entire management of the train is placed in the hands of the engineer, who can at once apply every brake

[1] *Brake* oder *break* Bremse. [2] Bremser. [3] selbstwirkend. [4] Block, Bremsblock; *block brake* Blockbremse, *brake-lever* Bremshebel, *skid, slipper drag, shoe* Hemmschuh. [5] Feder. [6] hinteres Treibrad. [7] Spur einer Rolle, s. Teil II, Nr. 7. [8] atmosphärische Bremse. [9] Luftpumpe. [10] Kessel, s. Teil II. [11] Trittbret. [12] Kolben. [13] Gasrohr. [14] Gummischlauch. [15] verkuppeln. [16] Ventil.

in the train with the utmost force, or as quickly release the same. Trains have been stopped while running at speeds from 30 to 40 miles an hour, by the above brake, in as short a distance as 400 feet. A train of six cars, running down a 96 feet grade[17], upon the Pennsylvania Railroad, at 30 miles an hour, was stopped in a length of 420 feet. Safety, comfort, and economy are at once attained by applying the retarding power to all parts of the train alike; and this is done by the Westinghouse Brake.

VOSE, *Manuals for Railroad Engineers.*

The following figures derived from the careful report of the 'Engineering' newspaper on experiments conducted by the committee appointed by the Royal Commissioners on railway accidents, will show the power of the several breaks in arresting trains of known weight at known speeds and on the same railway. The experiments given are those in which the engine was not reversed. The trains in all cases consisted of an engine, tender, two break vans[18], and thirteen carriages. The state of the rails is a most important factor in the arresting power of breaks. It was shown in these experiments that the same break applied to the same train requires from

Total weight of train including weight of engine.	Description of brake used.	Speed of train when brakes where applied.	Distance run after application of brakes.	Time occupied in making the stop.	State of the rails.	Equivalent distance which would have been run by the train if the speed when the brakes were applied had been 50 miles per hour.
tons cwt.		miles per hour.	feet.	secs.		feet.
203 4	Westinghouse Automatic	52	913	19	dry	844
198 4	Clark's Hydraulic	52	1212	22¾	dry	1121
186 13	Fay's	44½	1165	27½	wet	1471
262 7	Smith's Vacuum	49½	1448	29	dry	1477
241 10	Clark and Webb's	47½	1337	29	dry	1481
210 2	Barker's Hydraulic . . .	50¾	1549	32	dry	1503
204 3	Westinghouse Vacuum .	52	1728	34½	wet	1598
197 7	Steel and M'Innes' . . .	49½	1603	34½	wet	1636
241 10	Ordinary brakes on tender and break vans	49½	2389	63	dry	2437
197 8		49½	3205	86	dry	3270
198 4		49½	3265	83½	wet	3331
257 13		49½	3591	87	wet	3664
204 3		49½	3705	96	wet	3780

[17] Gefälle, Steigung. [18] Bremswagen.

30 to 40 per cent. more space to pull up in when the rails are wet than when they are dry. The ill effect, however, of wet rails may be to some extent reduced by sanding the rails from well-contrived sand-boxes [19], which should be so arranged as to be self-acting in cases of emergency.

BARRY, *Railway Appliances.*

8. INTERLOCKING APPARATUS.

FIG. 4 shows a locking apparatus of the most modern description actuated exclusively by the spring catch-rod. In this arrangement the whole of the locking gear is above the floor and in sight of the signalman, and easily accessible for oiling and repair. The movement of the spring catch-rod works the locking, and consequently the locks are put on or taken off at each end of the stroke of the lever when the spring catch is raised out of, or allowed to fall into, the notch in the quadrant. The principal novelty in the mechanism is the rocker, D, which is a 'slot link' or segmental plate with a curved slot in it. The lower end of the spring catch-rod carries a stud, upon which is a small block, B, travelling in the curved slot in the rocker. When the main lever is in its normal position, and to the front of the frame, and the spring catch-rod is down, the left-hand end of the rocker is depressed and the right-hand end raised, as shown in fig. 4, by the dotted lines of the more distant rocker. Upon raising the spring catch-rod out of the notch in the quadrant, the rocker is moved into a position as shown in the nearer rocker in the drawing, in which position the curve of the slot corresponds to the radial course of the block when the main lever is being moved. The nearer lever, C, is shown out of its normal position, the spring catch-rod being raised, and the rocker being therefore in the second position. As the spring catch can fall only into the notches at each end of the quadrant it follows that the rocker is not moved during the stroke of the lever, because the stud when the lever is moved only travels in a slot which is radial to the centre on which the lever itself moves. When, however, the main lever is over, and the spring catch-rod is let down into the notch at the back of the frame, the rocker is moved to a third position with the left-hand end high and the right-hand end low. At the left-hand end of the rocker is a jaw which carries a universal jointed vertical link E. This link gives motion to a small crank at the end of a spindle, the bearings of

[19] Sandstreuer.

which are shown at G G. The intermediate portion of these spindles is flat, and when they stand in their normal position the locking bars are free to travel over them, as shown at H; but when they

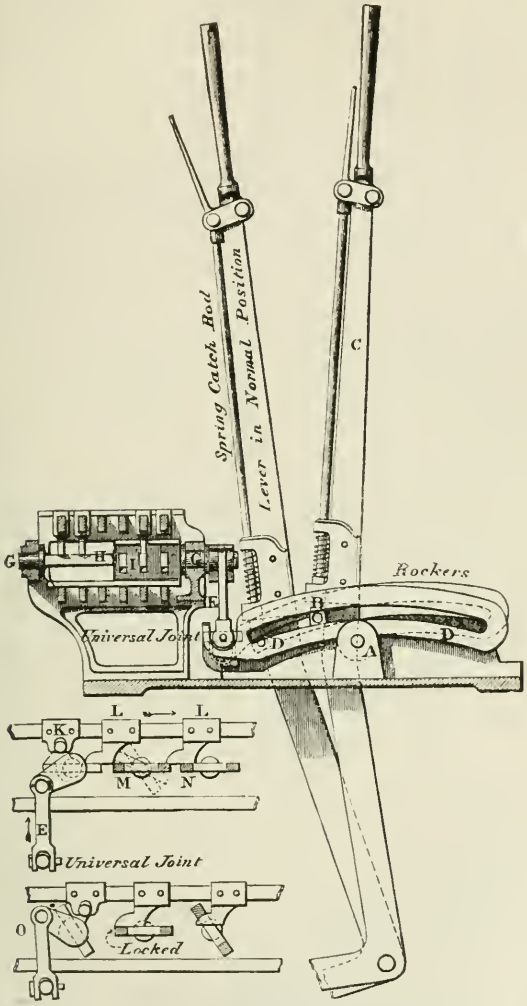

Fig. 4. Modern Interlocking Apparatus actuated by spring catch-rod.

are canted up (as in the case of the spindle shown broken off at I) they offer an obstruction to the movement of the locks attached to the locking bars. The action of the locking will be more readily

understood by referring to the two front views given in the left-hand corner of fig. 4. In the upper view it is assumed that the rocker connected with the vertical link E is in the first position, the link E is in its normal position, the crank is inclined downwards, and the flat part of the spindle is horizontal. The two other spindles, M and N, are those worked by the rockers of the two adjoining levers, but their cranks are removed in order to show a section of the spindles. Each spindle that works a locking bar is provided with a short vertical crank, the stud of which works between two horns on the locking bar, as shown at K, so that when the spindle is moved a horizontal motion is given to the bar. The locks, L L, are fixed on the locking bar in such positions that some of the spindles are free to move, as at M, and some are locked, as at N. It will now be understood that whenever the spring catch of any lever is raised its rocker is lifted, and the corresponding spindle is turned; thus a very small amount of movement of the spring catch will cant the spindle up sufficiently to prevent the appropriate locks from being moved. The spindles being connected to the rockers may, like them, occupy three positions. These are shown at M: 1st, the normal, or horizontal position, is shown by full lines; 2nd, an intermediate position, when the main lever is being moved, as shown by dotted lines; and 3rd, the third position (also shown by dotted lines) is that which the spindle occupies when the main lever has been pulled over and the spring catch released. The right-hand end of the rocker is then depressed, and the other end with its link raised, as shown at O, in the lower front view. The third position of the rocker plays a very important part in the locking, because until that position is fully attained some of the locks are not released. If, for instance, a spindle stands locked, as shown at N, it is not released until by the movement of another spindle into the third position, shown at O, the lock on the locking bar has travelled sufficiently in the direction of the arrow to stand over a hole in the flat spindle N, in which case the spindle can be turned up in front of the projecting beak of the lock, as shown in the case of the right-hand spindle in the lower view. The spindle N now prevents the return movement of the lock, and consequently the point lever which, by means of the link, O, works the left-hand spindle, cannot be moved until the flat spindle, N, has been replaced in its first or horizontal position corresponding to the lowering of the spring catch-rod of its lever into the forward notch of the quadrant.

The machine above described indicates one of the methods of carrying out the principles aimed at in the best interlocking apparatus, which are that a signalman should not be able even to commence to make any movement of either points or signals until he has efficiently locked in their proper positions all points and

signals that have any relation to the movement which he intends to make; and that until he has thoroughly completed the intended movement, and has ceased to meddle with the part of the apparatus which actually sets the points or signals in motion, all points or signals affecting the operation which he is performing must be securely locked.

J. W. Barry, *M.I.C.I.*

9. ATMOSPHERIC RAILWAYS.

The idea of conveying carriages in a tube[1] by means of atmospheric pressure[2] seems to have originated with Dr. Papin, of Blois, in France, about the end of the seventeenth century. This extremely versatile man was the first to apply steam to raising a piston[3] in a cylinder. He was the inventor of the Digester[4], and to this was first applied the lever-weighted safety-valve[5], also the Doctor's invention. The experiments actually entered upon by the philosopher of Blois, in the matter of compressed[6] air, were principally directed to the transmission of power thereby. He placed air-compressing engines in positions where the compression could be effected by a fall of water, and pipes[1] were to convey the air to the mine, where it was to be allowed to expand against a piston and work a pump. For some reason the project failed in its execution, but has been more successful in other hands.

The suggestion of conveying goods, parcels, and passengers by compressed air appears to have been rather a chance suggestion than to have been seriously entertained, and it has been again and again revived in the 130 years that intervened between Papin and Medhurst, who again urged the project about 1810.

Medhurst, in 1810, published an account of "a new method of conveying goods and letters by air", and in 1812 extended the idea so as to provide for the transmission of passengers, whom he proposed to transport at the rate of fifty miles per hour. His project consisted of an air-tight[7] tube, containing a pair of cast-iron wheel-tracks[8] on which the carriage has to run. The carriage had the form of the tube and a certain amount of packing[9] to prevent the leakage of the air, which was condensed behind it and formed the propelling power.

Twelve years afterward the idea was revived in a changed form. Retaining the tube and carriage of Medhurst, Vallance, in 1824, obtained a patent in England for his modified plan, which

[1] Röhre. [2] Luftdruck. [3] Kolben. [4] Papin'scher Topf. [5] Sicherheitsventil mit Hebelbelastung. [6] comprimiren; *air-compressing engine*, *condensing pump* Compressionsmaschine, Compressionspumpe. [7] luftdicht. [8] Gleis. [9] Liderung.

consisted in using a partial vacuum[10] in front of the carriage, allowing the natural atmospheric pressure in the rear to impel the carriage. In this he differed from Papin and Medhurst, who proposed a plenum in the rear, and not a vacuum in the advance.

So far all the inventors have proposed that the carriage shall travel in the tube in the manner of a piston. The next proposition introduces a new feature.

In 1834, Pinkus, an American citizen residing in England, took out a patent for an apparatus which he termed a Pneumatic Railway, and laid the foundation of most of the successful applications of the atmospheric principle which have since been introduced.

Pinkus's patent embraces a main[11] with a continuous longitudinal slot[12] on its upper surface, and an elastic gravitating valve[13] to fill the slot. The tube was to be about forty inches in diameter, laid down between a pair of rails on which the carriages were to run, and having within it a piston attached by a vertical arm to the leading carriage of the train. The vertical arm passed through the slot in the upper part of the tube, and displaced the valve as the piston advanced, the valve closing in the rear of the arm after allowing some air to enter. The valve consisted of a thick cord saturated with a composition of wax and tallow.

Clegg patented some improvements in 1839. The valve works on a hinge[14] of leather or other flexible material, which is practically air-tight, similar to the valves commonly used in air-pumps[15]; the extremity or edge of the valve is caused to fall into a trough containing a composition of beeswax and tallow, or other substance which is solid at the temperature of the atmosphere, and becomes fluid when heated a few degrees above it. The tube was coated[16] inside with hard tallow, to make it perfectly smooth, and the piston was furnished with a rod[17], about 14 feet long, to which were attached rollers[18], which pressed open an air-tight valve along the top of the tube as the piston advanced. The piston was attached to the first, or driving, car by means of a colter, and to the driving car was attached a copper vessel, several feet in length, heated with coke, for the purpose of melting the composition after the valve had been pressed down by the closing roller.

Railroad engineers expressed very various opinions on the feasibility of the new project, Brunel and Stephenson took opposite sides, as usual, and the plan was tried in South Devonshire, on the Croydon Railway, and elsewhere. It eventually failed by reason of complexity and liability to get out of order, leakage of air impairing the vacuum.

The advantages are: facility in ascending heavy grades[19], ren-

[10] luftleerer Raum. [11] Rohr, Hauptleituugsrohr. [12] Coulisse. [13] Ventil. [14] Scharnier. [15] Luftpumpe. [16] überziehen. [17] Stange. [18] Rolle, Walze. [19] Steigung; *grading* Planirung.

dering less cost necessary in levelling and grading; and security against collision.[20]

Another form of conveying the motion of the piston in the atmospheric tube was invented by Pilbrow, and was intended to avoid the continuous opening in the tube, and the necessity for the valve which closed it on the Pinkus principle. Pilbrow made a toothed rack[21] on the edge of his piston, which rack engaged with a series of pinions[21] in air-tight boxes attached to the sides of the tube at short intervals. The vertical axes of these pinions passed upward through stuffing-boxes[22], and at the top were provided with other pinions which geared[23] into racks on the sides of the carriages. Thus, the motion of the piston rotates the pinions successively as it advances along the line, and they communicate motion to the carriage.

Keene and Nickel's Atmospheric Railway (English) was designed to act by compressed air in a tube laid along, under ground, between the lines of rail.[24] Stationary above the surface are certain standards with grooved sides, in which are elastic pipes fed from the reservoir-pipe below. Beneath the carriage to be driven are rollers which are made to condense the elastic pipes into the hollowed sides, and the air, being admitted in the rear, expands against the peripheries of the drums beneath the carriage, and forces them to rotate and the carriage to advance.

Henry's Atmospheric Railway, English Patent, August 7, 1845, specifies a side slit in the atmospheric tube, and the longitudinal valve closed by the pressure of a long bag or hose[25], inflated with air and protected by a shield of wrought-iron bolted to the tube. The vacuum in the tube is produced by first filling with water a number of large, close reservoirs connected with the tube by pipes and valves, opening the communication between the two, and then allowing the water to run off.

In one form (Atmospheric Elevated Railway), the tube, which extends the whole length of the railway, is filled with compressed air, for the supply of the tanks[26] on the cars, which form reservoirs for the supply of the air whereby the air-engines are driven. The tube at suitable intervals has valves and discharge-pipes for the supply of the engines on the cars.

The original proposition to use a transportation-tube and compression or exhaustion of air for the conveyance of lighter articles of freight and letters, has been put in practice successfully. A company was formed, and a permanent line laid down in 1859, for conveying parcels and light goods from the Euston Square Station and the Post-Office in Eversholt Street, London, and an extension was opened in 1865.

[20] Zusammenstoss. [21] Zahnstange; *pinion* Getriebe. [22] Stopfbüchse. [23] eingreifen. [24] Schiene. [25] Schlauch. [26] Behälter, Tender.

This realizes the dreams of Papin and the hopes of Medhurst, nearly two hundred years after the busy speculations of the first and fifty years after the disappointment of the second.

KNIGHT, *Mechanical Dictionary.*

10. THE FIRST PUBLIC RAILWAY.

WHILE the Stockton and Darlington Railway works were in progress, Mr. Stephenson had many interesting discussions with Mr. Pease, on points connected with its construction and working, the determination of which in a great measure affected the formation and working of all further railways. The most important points were these: 1. The comparative merits of cast and wrought-iron rails. 2. The gauge of the railway. 3. The employment of horse or engine power in working it, when ready for traffic.

The kind of *rails* to be laid down to form the permanent road was a matter of considerable importance. A wooden tramroad had been contemplated when the first Act was applied for; but Stephenson having advised that an iron road should be laid down, he was instructed to draw up a specification of the rails. He went before the directors to discuss with them the kind of material to be specified. He was himself interested in the patent for cast-iron rails, which he had taken out in conjunction with Mr. Losh in 1816; and, of course, it was of his interest that his articles should be used; but when requested to give his opinion on the subject, he frankly said to the directors: "Well, gentlemen, to tell you the truth, although it would put £ 500 in my pocket to specify my own patent rails, I cannot do so after the experience I have had. If you take my advice, you will not lay down a single cast-iron rail." "Why?" asked the directors. "Because they would not stand the weight, and you will be at no end of expense for repairs and relays." "What kind of road, then", he was asked, "would you recommend?" "Malleable rails, certainly", said he, "and I can recommend them with the more confidence from the fact that at Killingworth we have had some Swedish bars laid down—nailed to wooden sleepers—for a period of fourteen years, the waggons passing over them daily; and there they are, in use yet, whereas the cast rails are constantly giving way."

The price of malleable rails was, however, so high—being then worth about £ 12 per ton as compared with cast-iron rails at about £ 5 10*s.*—and the saving of expense was so important a consideration with the subscribers, that Stephenson was directed to provide, in the specification, that only one-half of the rails

required—or about 800 tons—should be of malleable iron and the remainder of cast-iron. The malleable rails were of the kind called "fish-bellied", and weighed 28 lbs. to the yard, being $2\frac{1}{4}$ inches broad at the top, with the upper flange $\frac{3}{4}$ inch thick. They were only 2 inches in depth at the points at which they rested on the chairs, and $3\frac{1}{4}$ inches in the middle or bellied part.

When forming the road, the proper *gauge* had also to be determined. What was this to be? The gauge of the first tramroad laid down had virtually settled the point. The gauge of wheels of the country—of the carts and waggons employed on common roads, which were first used on the tramroads—was about 4 feet $8\frac{1}{2}$ inches. And so the first tramroads were laid down of this gauge. The tools and machinery for constructing coal-waggons and locomotives were formed with this gauge in view. The Wylam waggon-way, afterwards the Killingworth railroad, were as nearly as possible on the same gauge. Some of the earth-waggons used to form the Stockton and Darlington road were brought from the Hetton railway; and others which were specially constructed were formed of the same dimensions, these being intended to be afterwards employed in the working of the traffic.

As the period drew near for the opening of the line, the question of the *tractive power* to be employed was anxiously discussed. At the Brusselton incline, fixed engines must necessarily be made use of; but with respect to the mode of working the railway generally, it was decided that horses were to be largely employed, and arrangements were made for their purchase. The influence of Mr. Pease also secured that a fair trial should be given to the experiment of working the traffic by locomotive power; and three engines were ordered from the firm of Stephenson and Co., Newcastle, which were put in hand forthwith, in anticipation of the opening of the railway. These were constructed after Mr. Stephenson's most matured designs, and embodied all the improvements which he had contrived up to that time. No. 1. engine, the "Locomotion", which was first delivered, weighed about eight tons. It had one large flue or tube through the boiler, by which the heated air passed direct from the furnace at one end, lined with fire-bricks, to the chimney at the other. The combustion in the furnace was quickened by the adoption of the steam blast in the chimney. The heat raised was sometimes so great, and it was so imperfectly abstracted by the surrounding water, that the chimney became almost red-hot. Such engines when put to their speed, were found capable of running at the rate of from twelve to sixteen miles an hour; but they were better adapted for the heavy work of hauling coal-trains at low speeds—for which, indeed, they were specially constructed—than for running at the higher speeds afterwards adopted. Nor was it contemplated by the directors as possible, at the time when they

were ordered, that locomotives could be made available for the purposes of passenger travelling. Besides, the Stockton and Darlington Railway did not run through a district in which passengers were supposed to be likely to constitute any considerable portion of the traffic.

The Stockton and Darlington line was opened for traffic on the 25th September, 1825. An immense concourse of people assembled from all parts to witness the ceremony of opening this first public railway. The powerful opposition which the project had encountered, the threats which were still uttered against the company by the road-trustees and others, who declared that they would yet prevent the line being worked, and perhaps the general unbelief as to its success which still prevailed, tended to excite the curiosity of the public as to the result. Some went to rejoice at the opening, some to see the "bubble burst", and there were many prophets of evil who could not miss the blowing up of the boasted travelling engine. The opening was, however, auspicious. The proceedings commenced at Brusselton Incline, about nine miles above Darlington, where the fixed engine drew a train of loaded waggons up the incline from the west, and lowered them at the east side. At the foot of the incline a locomotive was in readiness to receive them, Stephenson himself driving the engine. The train consisted of six waggons loaded with coals and flour; after these was the passenger-coach, filled with the directors and their friends, and then twenty-one waggons filled up with temporary seats for passengers; and lastly came six waggon-loads of coal, making in all a train of thirty-eight vehicles. The local chronicler of the day almost went beside himself in describing the extraordinary event:—"The signal being given", he says, "the engine started off with this immense train of carriages, and such was its velocity, that in some parts the speed was frequently 12 miles an hour!" By the time it reached Stockton there were about 600 persons in the train or hanging on the waggons, which must have gone at a safe and steady pace of from four to six miles an hour from Darlington. "The arrival at Stockton", it is added, "excited a deep interest and admiration".

The working of the line then commenced, and the results were such as to surprise even the most sanguine of its projectors. The traffic upon which they had formed their estimates of profit proved to be small in comparison with that which flowed in upon them which they had never dreamt of. Thus, what the company had principally relied upon for their receipts was the carriage of coals for land sale at the stations along the line, whereas the haulage of coals to the seaports for exportation to the London market was not contemplated as possible. When the bill was before Parliament, Mr. Lambton (afterwards Earl of Durham) succeeded in getting a clause inserted, limiting the charge for the haulage of all coals to Stockton-on-Tees for the purpose of shipment to $\frac{1}{2}d.$ per ton per

mile; whereas a rate of 4*d.* per ton was allowed to be taken for all coals led upon the railway for land sale. Mr. Lambton's object in enforcing the low rate of ½*d.* was to protect his own trade in coal exported from Sunderland and the northern ports. He believed, in common with every body else, that the ½*d.* rate would effectually secure him against competition on the part of the Company; for it was not considered possible to lead coals at that price, and the proprietors of the railway themselves considered that such a rate would be utterly ruinous. The projectors never contemplated sending more than 10,000 tons a year to Stockton, and those only for shipment as ballast; they looked for their profit almost exclusively to the land sale. The result, however, was as surprising to them as it must have been to Mr. Lambton. The ½*d.* rate which was forced upon them, instead of being ruinous, proved the vital element in the success of the railway. In the course of a few years, the annual shipment of coal, led by the Stockton and Darlington Railway to Stockton and Middlesborough, was more than 500,000 tons; and it has since far exceeded this amount. Instead of being, as anticipated, a subordinate branch of traffic, it proved, in fact, the main traffic, while the land sale was merely subsidiary.

The anticipations of the company as to passenger traffic were in like manner more than realized. At first, passengers were not thought of; and it was only while the works were in progress that the starting of a passenger coach was seriously contemplated. The number of persons travelling between the two towns was very small; and it was not known whether these would risk their persons upon the iron road. It was determined, however, to make trial of a railway coach; and Mr. Stephenson was authorized to have one built at Newcastle, at the cost of the company. This was done accordingly; and the first railway passenger-carriage was built after our engineer's design. It was, however, a very modest, and indeed a somewhat uncouth machine, more resembling the caravans still to be seen at the country fairs containing the "Giant and the Dwarf" and other wonders of the world, than a passenger-coach of any extant form. A row of seats ran along each side of the interior, and a long deal table was fixed in the centre; the access being by means of a door at the back end, in the manner of an omnibus. This coach arrived from Newcastle the day before the opening, and formed part of the railway procession above described. Mr. Stephenson was consulted as to the name of the coach, and he at once suggested "The Experiment", and by this name it was called. The Company's arms were afterwards painted on her side, with the motto "*periculum privatum utilitas publica*". Such was the sole passenger-carrying stock of the Stockton and Darlington Company in the year 1825. But the "Experiment"

proved the forerunner of a mighty traffic: and long time did not elapse before it was displaced, not only by improved coaches (still drawn by horses), but afterwards by long trains of passenger-carriages drawn by locomotive engines.

The "Experiment" was started as a passenger-coach on the 10th October, 1825, a fortnight after the opening of the line. It was drawn by one horse, and performed a journey daily each way between the two towns, accomplishing the distance of twelve miles in about two hours. The fare charged was a shilling without distinction of class; and each passenger was allowed fourteen pounds of luggage free. The "Experiment" was not, however, worked by the company, but was let to contractors who worked it under an arrangement whereby toll was paid for the use of the line, rent of booking-cabins, &c.

The speculation answered so well that several private coaching companies were shortly after got up by innkeepers at Darlington and Stockton, for the purpose of running other coaches upon the railroad; and an active competition for passenger traffic sprang up. The "Experiment" being found too heavy for one horse to draw, besides being found an uncomfortable machine, was banished to the coal district. Its place was then supplied by other and better vehicles—though they were no other than old stage-coach bodies purchased by the company, and each mounted upon an underframe with flange-wheels. These were let on hire to the coaching companies, who horsed and managed them under an arrangement as to tolls, in like manner as the "Experiment" had been worked. Now began the distinction of inside and outside passengers, equivalent to first and second class, paying different fares. The competition with each other upon the railway, and with the ordinary stage-coaches upon the road, soon brought up the speed, which was increased to ten miles an hour—the mail-coach rate of travelling in those days, and considered very fast.

Mr. Clephan, a native of the district, has described some of the curious features of the competition between the rival coach companies. There were two separate coach companies in Stockton, and amusing collisions occurred between the drivers—who found on the rail a novel element for contention. Coaches cannot pass each other on the rail as on the road; and as the line was single, with four sidings for the mile, when two coaches met, or two trains, or coach and train, the question arose which of the drivers must go back? This was not always settled in silence. As to trains, it came to be a sort of understanding that empty should give way to loaded waggons; and as to trains and coaches, that the passengers must have preference over coals; while coaches when they met, must quarrel it out. At length, midway between sidings, a post was erected, and a rule was laid down that he who had passed

the pillar must go on, and the "coming man" go back. At the Goose Pool and Early Nook, it was common for these coaches to stop; and there, as Jonathan would say, passengers and coachmen "liquored". One coach, introduced by an innkeeper, was a compound of two mourning-coaches — an approximation to the real railway-coach, which still adheres, with multiplying exceptions, to the stage-coach type. One Dixon, who drove the "Experiment" between Darlington and Shildon, is the inventor of carriage-lighting on the rail. On a dark winter night, having compassion on his passengers, he would buy a penny candle and place it lighted amongst them on the table of the "Experiment" — the first railway coach (which, by the way ended its days at Shildon as a railway cabin) being also the first coach on the rail (first, second and third class jammed all into one) which indulged its customers with light in darkness.

The traffic of all sorts increased so steadily and so rapidly that considerable difficulty was experienced in working it satisfactorily. It had been provided by the first Stockton and Darlington Act that the line should be free to all parties who chose to use it at certain prescribed rates, and that any persons might put horses and waggons on the railway, and carry for himself. But this arrangement led to increasing confusion and difficulty, and could not continue in the face of a large and rapidly-increasing traffic. The goods trains got so long that the carriers found it necessary to call in the aid of the locomotive engine to help them on their way. Then mixed trains of passengers and merchandise began to run; and the result was that the railway company found it necessary to take the entire charge and working of the traffic. In course of time new coaches were specially built for the accommodation of the public, until at length regular passenger trains were run, drawn by the locomotive engine — though this was not until after the Liverpool and Manchester Company had established this as a distinct branch of their traffic.

The three Stephenson locomotives were from the first regularly employed to work the coal trains; and their proved efficiency for this purpose led to the gradual increase of the locomotive power. The speed of the engines — slow though it seems now — was in those days regarded as something marvellous. A race actually came off between Nr. 1. engine, the "Locomotion", and one of the stage-coaches travelling from Darlington to Stockton by the ordinary road; and it was regarded as a great triumph of mechanical skill that the locomotive reached Stockton first, beating the stage-coach by about a hundred yards! The same engine continued in good working order in the year 1846, when it headed the railway procession on the opening of the Middlesborough and Redcar Railway, travelling at the rate of about fourteen miles an hour. This

engine, the first that travelled upon the first public railway, has recently been placed upon a pedestal in front of the railway station at Darlington.

SMILES, *Life of Stephenson.*

11. TUNNELLING.*

As tunnels [1], compared with open excavations [2], are an expensive and tedious class of works, and as they form inconvenient portions of a line of communication, the engineer should study to avoid the necessity for them as far as possible.

The most favourable material for tunnelling is rock that is sound and durable without being very hard. Great hardness of the material increases the time and cost of tunnelling, but gives rise to no special difficulty. A worse class of materials are those which decay and soften by the action of air and moisture, as some clays [3] do; and the worst are those which are constantly soft and saturated [4] with water, such as quicksand [5] and mud. [6]

The engineer should, as far as possible, avoid curved tunnels, especially those in which the curvature [7] is so sharp or so extensive as to prevent daylight from being seen through from end to end. As to the figure of tunnels which require a lining [8] of brickwork or masonry to prevent fragments of rock from falling from the roof, or to sustain the pressure of earth, the elliptic or horseshoe form [9] is generally adopted, with an inverted arch [10] at the floor. [11]

Shafts or *pits* are sunk [12] for three purposes: to ascertain the nature of strata to be excavated, when they are called *trial shafts* [13]; to give access to a tunnel when in progress [14], for the purpose of carrying on the work, removing the material excavated, admitting fresh and discharging foul air, and pumping out water, when they are called *working shafts* [15]; to admit light and fresh air at intervals to, and remove foul air from, a tunnel when completed, when they are called *permanent shafts.* [16] Trial shafts are in general sunk at or near the centre line [17] of the proposed tunnel. The shape is regulated by the material to be used in lining the shaft, being rectangular in timbered [18] shafts, and cylindrical in those that are "steined" [19] or lined with stone or brick. When a working shaft is to be used in order to drain [20] the tunnel of water as the

[1] *Tunnel* Tunnel, *tunnelling* Tunnelbau, *centre line* Tunnelaxe. [2] s. Nr. 2. [3] Thon, s. T. I, Nr. 34, 1. [4] gesättigt. [5] Schwimmsand. [6] Schlamm. [7] Krümmung, s. Nr. 4,3 3. [8] Verkleidung. [9] elliptische oder Hufeisenform. [10] umgekehrter Bogen. [11] Sohle. [12] *to sink a shaft* einen Schacht abteufen. [13] Probeschacht. [14] im Bau. [15] Arbeitsschacht, Förderschacht. [16] Luftschacht, vergl. Teil I, Nr. 25, 18. [17] Tunnelaxe. [18] auszimmern. [19] ausmauern. [20] entwässern.

* S. *Technical Vocabulary*, S. 175 u. 103.

work proceeds, it is sunk to such a depth below the bottom[11] of the excavation as to form a sufficient reservoir for water, called a *sump*[21], from which the water is raised by a windlass[22] and bucket[23], or by a pump. The most convenient form of bucket is one that is hung in a stirrup[24] by a pair of trunnions[25] whose axis nearly traverses the centre of gravity[26] of the bucket. When lowered, the bucket is held upright by a catch[27]; and after it has been raised, the removal of the catch allows it to be easily tilted over[28], in order to discharge the water. Permanent shafts are in general working shafts that have been made permanent parts of the structure, the brick lining of each being supported on a permanent "curb"[29], or suitably formed ring of brickwork or of cast iron, surrounding a circular orifice in the roof of the tunnel. The top of each shaft is protected by being surrounded with a wall, and covered with a grating.

Sinking shafts in sound rock is performed simply by the operations of blasting[30] and quarrying.[31] Ventilating apparatus[32] is indispensable when foul air (such as carbonic acid gas[33], or "choke damp") or inflammable[34] gas ("fire damp"[35]) is disengaged from the strata that are traversed by the shaft. When water flows into the shaft, it is to be collected at the bottom in a "sump" or well, and raised by buckets or by pumping, either to the surface of the ground or to some drift[36] through which it can be discharged.

A shaft sunk through soft materials, or through loose rock, must be lined with timber, masonry, or brickwork.

The principal pieces in *timbering* a shaft[37], as well as in the timbering of drifts, tunnels, and underground excavations in general, may be distinguished into *props*[38] which are struts[39] or posts[40], either vertical or raking, and usually of round timber[41]; *sills* and *bars*[42], being horizontal pieces, sometimes round and sometimes squared[43]; and *cleading* or *boards*, *poling-boards*.[44] Props are combined with sills or bars into framework simply by abutting joints[45] at their ends, which are made fast in their places by the aid of spikes[46] called "*brobs*".

Sinking stone or brick-lined shafts (which are usually cylindrical) may be effected in two ways; by "*underpinning*"[47], or by a "*drum-curb*".[48]

Drifts, *mines*, or *headings*[49], are small horizontal or inclined underground passages, made in order to explore the strata in the line of an intended tunnel, to drain off water, and to facilitate the

[21] Sumpf. [22] Haspel, Winde. [23] Kübel. [24] Bügel. [25] Zapfen. [26] Schwerpunkt. [27] Klinke. [28] umkippen. [29] Kranz. [30] Sprengen. [31] Brechen, Steinbrechen. [32] Ventilationsvorrichtung. [33] Kohlensäure. [34] entzündlich. [35] schlagende Wetter. [36] Stollen. [37] Schachtzimmerung. [38] Stempel. [39] Strebe, Spreize. [40] Pfosten, Säule. [41] Rundholz. [42] *sill* Schwelle; *ground-sill* Sohlschwelle, *cap-sill* Kappholz, *cap* Kappe, *bar* Balken, *setting* Gevier. [43] (vicreckig) behauen. [44] Verschalung, Verpfählung, Verladung, die Pfähle Schalbretter, Laden. [45] stumpfer Stoss. [46] Schienennagel, Hakennagel. [47] Unterfangen. [48] Brunnenbüchse; *curb* oder *crib* Kranz, *wedging crib* Keilkranz, *spiking crib* Nagelkranz. [49] Strecke, Stollen; *cross heading* Querschlag.

ranging[50] of the line and levels and setting out[51] of the works, the access of the workmen, and the transport of materials; and for the last-mentioned purpose they are often furnished with small temporary railways. The working shafts of a tunnel are almost always connected together by means of a heading, which, accordingly, runs either along or parallel to the centre line of the tunnel. In some cases the heading runs along the centre line, while the working shafts lie at one side, and are connected with the main heading by cross headings. In tunnelling through soft and wet ground the most convenient level for the principal heading is at or near the bottom of the tunnel. In hard and dry materials it may be placed near the roof. Headings in solid rock are driven by blasting and quarrying. Machinery has been used for driving headings.[52]*

Tunnels in dry and solid rock are in general excavated by driving a heading immediately below the intended roof of the tunnel, from which heading the excavation is extended sideways and downwards by blasting and quarrying.

Tunnels in dry fissured[52] *rock* require arching within, to guard against the fall of portions of the roof. The most convenient way to make them is in general to commence at a heading running along close below the roof of the excavation[53]; to extend the excavation sideways and downwards to the floor at each side of the tunnel, leaving a wall of rock standing in the middle. This wall is used as a pier to support temporary props (should such be required) for the roof of the excavation, and also to support the centres[54] for the arching[55], which is carried forward as close behind the excavation as the convenience of working will admit. When the arching is complete, and the centres struck, the central wall of rock is cut away. All hollows between the brickwork and the rock should be carefully filled with concrete.

Tunnels in soft materials require timbering to support the sides and top of the excavation, constructed on the same principles with that of headings. In such tunnels a principal heading[56] is in general required at the level of the floor, for purposes of drainage.[57] The excavation of the tunnel is carried on in various ways; that which will here be described is the method of which a detailed account is given by Mr. Simms in his *Practical Tunnelling*.

The tunnel is executed in *lengths*[58], each of about 12 or 15 feet. These are designated as follows, in the order in which they are executed:—

Side lengths[59], on each side of a working shaft.

Leading lengths[60], in prolongation of the tunnel from the side lengths.

[50] Ausstecken. [51] Abstecken, s. Nr. 1. [52] klüftig. [53] Ausbruch. [54] Lehrbogen, Lehrgerüst. [55] Wölbung. [56] Hauptstollen, Richtstollen. [57] Entwässerung. [58] Ausbruchlänge. [59] Seitenlänge. [60] Richtlänge.

* S. Nr. 12 *"Rock-boring Machinery"*.

Junction lengths[61], where two portions of the tunnel meet midway between two shafts.

Shaft lengths[62], directly under the working shafts.

The first operation in commencing a side length, leading length, or junction length, is to drive a heading at the top of the excavation, whose roof must be $1\frac{1}{2}$ or 2 feet above the intended top of the brickwork. From that heading the excavation is extended sideways and downwards by a process exactly like that of driving a heading. The earth is supported by poling boards[44], which are supported by strong horizontal timbers called bars[63], 8 or 10 inches in diameter. The after ends of these bars are supported,—in side lengths, by props[38] resting on the framework[64] of the working shaft; in all other lengths, by the top of the arch of the previous length; and they are kept asunder by four or five struts[65] between each pair. The forward ends of the bars rest on props, each of which stands on a foot-block.[66] The bottom of the excavation is formed with great accuracy to receive the invert, or inverted arch, which forms the base of the brickwork. The arch of the roof is built upon centres, consisting of three ribs under each length. The best centres have ribs of iron, with screws under each lagging.[67] The centres are usually supported on cross sills[68], which are themselves supported partly by posts resting on the floor, and partly by their ends being inserted into holes in the side walls, which are built up after the centres are struck.

After the brickwork of a length has been built, most of the crown bars[63] which lie above the arch can be pulled forward so as to serve for the next length; those which resist this must be left. All spaces between the brickwork and the earth must be carefully rammed up.* RANKINE, *Civil Engineering.*

* Great accuracy has been attained in the alignment of tunnels so as to secure accurate meeting when working from both ends, or from several additional intermediate points. In making the Musconetcong tunnel, 5000 feet long, the estimated length deduced from chaining and levelling over a mountain 450 above grade, varied from the actual length $6\frac{4}{10}''$; the center lines of the headings varied $\frac{1}{300}''$. The Hoosac tunnel, through the mountain of that name, on the railway between Troy, N. Y., and Greenfield, Mass., 25,031 feet long (the longest tunnel in the United States), with an ascending grade of $26\frac{4}{10}'$ to the mile, had an error of alignment when the headings met of $\frac{9}{16}''$, and of level $1\frac{1}{2}''$. The Mont Cenis tunnel, 30,326 feet long, level on Italian side 435 feet above the French entrance, and the level in the middle 10 feet above the Italian entrance, the error in alignment was 18″, and in level 24″; the French above the Italian. KNIGHT.

[61] Anschlusslänge. [62] Schachtlänge. [63] *crown bar* Kronbalken. [64] Rahenwerk. [65] Spreize, Spannriegel. [66] Fussklotz. [67] Schalholz eines Lehrbogens, Lehrbogenschalung. [68] Querschwelle.

12. ROCK-BORING MACHINERY.

The application of machinery to the boring of holes for blasting[1] purposes is a subject of considerable importance. By means of boring machines[2] shafts may be sunk[3], levels driven[4], and lodes[5] explored in one-third of the time required to effect the work by manual labour[6] alone, while dead charges, such as water, cost, management, and maintenance[7] of works, may be proportionally lessened, and the chance of realising satisfactory results for the capitalists materially increased.

For the purpose of driving percussion boring machines[8] at the bottom of shafts or in subterraneous headings[9], pneumatic power is desirable. Such power can be transmitted to a great distance without difficulty, and will in its use not only supply air to workmen, but naturally aid in expelling the gases resulting from firing explosive compounds.[10]

Mechanical boring, to afford satisfactory results, involves a well-devised system of working, in which time, the unit of cost and expression of the result, may be employed to the fullest and most beneficial extent. If a high rate of progress be required, two or more boring machines must run together, and the machines, whatever their number, mounted[11] in such a way as to be readily shifted[12] to any part of the face.[13] Then, when the boring is complete, the tackle[14] must admit of its being quickly withdrawn. The shot holes[15] must also be readily charged[16] and blasted[17], and the *débris*[18] immediately removed. The apparatus necessary in connection with rock-boring machines consists of—compressing engines (or air compressors), air receivers[20], pipes[21] for the conveyance of compressed air, railways for carrying the boring tackle, carriages or stands[22] for mounting the boring machines, rock-boring machines, rock-boring tools[23]; while a 'cut' or 'sink'[24] includes—boring the holes, charging and blasting the holes, removal of the stuff[25] after the blasting operation.

The first inventor of a rock-boring machine seems to have been Trevithick. In the year 1813, when his attention was directed to the subject, Cornwall was not only the chief seat of mining industry, but, through the startling improvements effected in the steam-engine by Watt, Murdoch, Trevithick, Woolf, and others, an impetus was given to mechanical inventions which extended far beyond the confines of the county, and men were stimulated at home and abroad

[1] Sprengen. [2] Bohrmaschine. [3] *to sink a shaft* einen Schacht abteufen. [4] *to drive a level* einen Stollen treiben. [5] Gang, Erzgang, s. Teil I, Nr. 25. [6] Handarbeit. [7] Unterhaltung. [8] Stoss- oder Perkussionsbohrmaschine. [9] Strecke. [10] das Anzünden explosiver Verbindungen. [11] einspannen. [12] versetzen, fortrücken. [13] die Gesteinsbrust, der Ort. [14] Vorschubmechanismus. [15] Schussloch, Bohrloch. [16] besetzen. [17] wegthun, sprengen. [18] Trümmer. [19] Luftcompressionsmaschine. [20] Windregulator, Windkessel, Luftbehälter. [21] Rohrleitung. [22] (Bohr-)Gestelle. [23] Bohrgezähe. [24] Bohrung. [25] Gebirge (das abgesprengte, lose Material).

to substitute as far as possible mechanical appliances for manual labour. Some forty years, however, passed away before the idea of boring shot-holes by means of machinery was rendered practicable. The exigencies of the Mont Cenis Tunnel induced Bartlett to devise a steam rock-boring machine. Later Sommeiller invented the machine which bore his name, and showed how it could be worked by compressed air. Following Sommeiller's success in the Mont Cenis Tunnel, Italian, German, French, Swedish, American, Australian, and English engineers addressed themselves to the subject of inventing, contriving, and improving rock-boring appliances. Machines 10 ft. long, beset with complicated gear[26], are now replaced by machines 3 ft. long, presenting little more than the cylinder, valve, and a forwarding device.[27] All real and permanent improvements have tended in the direction of increased strength and simplicity of parts. In more particularly tracing the development of inventors' ideas for expediting tunnelling and mining operations, it will appear that they group themselves into — 1, forming the shot-hole by a revolving drill[28], and blasting the hole itself; 2, removing the entire area of the heading without the use of an explosive, either by means of a huge percussive[29], or a pressure cutting machine[30]; 3, boring shot-holes by means of a small percussion engine. The failure of the first method, that of employing an ordinary steel tool in hard silicious[31] rock, was soon rendered apparent; the tool, instead of abrading[32] the stone, was almost immediately destroyed. The second method—substituting mechanical, or mechanical and chemical force, also proved objectionable when applied to hard crystalline rocks. Apart from such machines, blocking[33] as it were the forebreast[34], the mechanical power required for performing the work was not only excessive, but the progress slow, and the greatest difficulty experienced in keeping the tools in condition for doing their work. The third method—the use of percussion borers in combination with chemical force, is the one which has been, and is likely to be, attended with permanent success. In perforating[35] a heading with the requisite number of shot-holes, only a minimum expenditure of mechanical power is required; the chief work, that of removing the rock, being effected by the superior agency of chemical force instantly developed by the detonation of an explosive compound.

In a percussion borer the movements required to form a hole are of a threefold character—1, a reciprocatory[36] movement of the piston and tool to disintegrate[37] the rock; 2, turning the piston and

[26] Getriebe, Räderübersetzung. [27] Zuschiebungsvorrichtung. [28] Rotationsbohrer, Drehbohrer. [29] Stossbohrmaschine. [30] Fraismaschine. [31] quarzhaltig. [32] abschaben, abreiben. [33] versperren. [34] Gesteinsbrust. [35] durchbohren. [36] hin- und hergehend. [37] zerkleinern.

tool during the reciprocatory movement; 3, advancing the tool as the hole is deepened. In one or two machines before the public these movements are automatically performed, and such automatic movements are desirable when four or six machines are worked together; but the forwarding or advance movement will be liable to fail in its object unless the rock be of uniform structure and hardness. In other boring machines the automatic movements are confined to the reciprocation and rotation of the piston, while in some, the piston and tool are rotated by hand.*

To perforate a face of rock quickly several conditions must be observed:—1. The machines must perform their work with certainty. 2. The number of machines should bear some general relation to the area of the face. 3. Stands are requisite for carrying the machines, not only as a means to keep the 'bit'[40] in line of the hole, but to admit of angling and shifting the machines quickly.

The Ferroux rock-boring machine, employed in the St. Gotthard Tunnel, in its general arrangement resembles Sommeiller's machine. In Ferroux's machine the triple operation of drilling, rotating the piston, and advancing the tool are automatically performed; but to obtain these movements the machine is necessarily of considerable length. The rotation of the tool and movement of the air valve are effected by means of an oscillatory engine placed at the end of the advance cylinder.[41] The advance cylinder is set next to the oscillatory cylinder, and is fitted with a cupped leather piston[42], the back or superior end of which piston is subject to the pressure of the motive fluid. The percussion cylinder[43] in front is filled with a slide valve shifted by a rotary disc-shaped cam.[44] The front of the piston rod immediately outside the cylinder gland[45] is furnished with an annular cam, the object of which is to lift a trigger lever[46] from the ratchet bars[47], so that the pressure on the forwarding piston may thrust the percussion cylinder and boring tool forward to such an extent that the trigger end of the lever is advanced beyond the action of the cam, thereby allowing the

* In the Mont Cenis Tunnel, a given number, ten machines, were grouped together on a carriage, the natural rupturing lines of the rock disregarded, the holes drilled more or less with the axial line of the heading, the machines and carriage withdrawn, the holes charged, the explosive fired, and the stuff removed. These series of operations constituted an 'advance', while in America and in one or two English mines, it is known as a 'cut', and in shafts as a 'sink'. Two distinct systems of arranging the shot-holes have been introduced, viz., the 'circular cut'[38], and the 'square cut.'[39] URE'S *Dictionary.*

[38] die kreisförmige Anordnung. [39] die Anordnung in geraden Reihen. [40] das Bohreisen. [41] Zuschiebungscylinder. [42] Kolben mit Lederpackung, Stulpenkolben. [43] Cylinder für die Stossbewegung. [44] Kurvenscheibe, Hubscheibe. [45] Deckel. [46] Sperrklinke. [47] gezahnte Stange.

opposite end of the lever to drop into the ratchet bars, and thus stay the advance of the tool and cylinder.*

The objects to be kept in view in the employment of rock-boring machinery are—the attainment of a high rate of speed at a moderate cost. To realise these two distinct results the tackle must be efficient, the work well organised, the roadways of proper dimensions for the removal of the stuff, the hauling arrangements[55] satisfactory, the contingencies incident to the work anticipated, and hindrances avoided. The use of boring machines will tend to make the levels[56] and circulating ways larger, to create forwarding facilities for the miner, to admit larger volumes of air to the underground openings, to lessen the severity of the miner's toil, and increase the rate of wages, as well as to multiply the chances of successful results for the capitalists.

J. DARLINGTON (URE'S *Dictionary, Supplement*, 1878).

* Shalburne's submarine rock-drill, employed for removing the obstructions at Hellgate, is supported on a semi-spheroidal hollow cast-iron base, having three steel feet, which insure its stability on the rock. The drill frame is conical in shape, and is made of wrought iron, the drill-shaft passing through an opening in its top. The drill is operated by two engines within a water-tight chamber, and supplied with steam from the boiler of a steam-tug[48]; its head is provided with diamond points, performing its work altogether by rotation. Live steam is supplied by a rubber pipe[49] passing through an exterior exhaust-pipe.[50] Electro-magnetic devices are caused to ring a bell when the hole is bored to the required depth, and also when the drill is removed from the hole. When the proper number are drilled, a diver descends and charges them with nitro-glycerine cartridges.[51]

Colonel von Schmidt, of San Francisco, has proposed to employ for tunnelling the Sierra Nevada, in order to supply water to the auriferous gravel-beds[52] of Placer County, an annular diamond-drill[53] eight feet in diameter, consisting of a large wheel, on whose edge the diamonds are set, cutting a circular groove[54] two inches in diameter, and having a central borer which drills a blast-hole. The apparatus is to be worked by compressed air; and when a sufficient depth is attained, three or four feet, it is to be run backward, and the cylindrical mass of rock removed by blasting. KNIGHT.

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13. THE SAINT GOTHARD TUNNEL.

AT the commencement of the present week, the great work of piercing the Saint Gothard Tunnel, which has been in progress for

48 Schleppdampfer. 49 Gummischlauch. 50 Auslassrohr. 51 Patrone. 52 Kieslager. 53 Diamantbohrer. 54 Rinne. 55 Fördereinrichtungen. 56 Streckensohle, Bausohle.

some eight years, was practically completed by the joining up of the headings of the north and south sides. We have on various occasions* published detailed illustrated particulars of the undertaking, but the present is a suitable occasion for giving a summarised account of the tunnel, and the works connected with it.

The Saint Gothard Tunnel forms a part of the Gothard railway system yet unfinished, which will join up the Swiss and Italian *réseaux*, and thus greatly facilitate communications between the North of Europe and the Mediterranean and Upper Italy. On the Swiss side the railway starts from Lucerne, and on the Italian, a railway commences at and runs along the left bank of Lake Majeur, the connexion being made near the frontier of the Swiss Canton of Tessin. The whole length of the system will be 165 miles, divided into the following sections:

	Miles.
Lucerne-Goldau	14.73
Zug-Goldau	9.62
Goldau-Fluelen-Goeschenen	1.43
Airolo-Biasca	65.70
Biasca-Bellinzona-Lucarno	25.46
Bellinzona-Lugano	16.33
Bellinzona-Magadino	15.32
Lugano-Chiasa	16.15

The Saint Gothard Tunnel, which is the most important work upon this system, passes through the Helvetic Alps between Goeschenen on the north side, and Airolo on the south, the distance between these places being about $9\frac{1}{4}$ miles. The rail level at the Goeschenen entrance is 3637.5 ft. above sea level, and 2204 ft. above Lake Lucerne. At Airolo the elevation above the sea is 3755 ft., and 3109 ft. above Lake Majeur. The total length of the tunnel is 16,295 yards, or 9.258 miles. To facilitate execution, it has been made in a straight line having a length of 16,312 yards, but at the Goeschenen end, it was necessary to construct a curved branch to join the alignment of the railway beyond. This leaves the straight portion of the tunnel, and bears away to the eastward, until it strikes the face of the mountain; the length of this curved portion is 475 ft. The gradients in the tunnel are approximately as follows, starting from the northern end:

Length	25,000 ft.	gradient	1 in 171 rising.
„	4,500 „	„	1 in 1000 to summit.
„	1,500 „	„	level.
„	4,000 „	„	1 in 200 falling.
„	14,000 „	„	1 in 500 „

* *Vide* ENGINEERING, vols. XIX, XX, XXII, and XXIII.

The tunnel is formed for a double line of rails, and its normal width is 24 ft. $11\frac{3}{16}$ in. at the level of the rails, increased to 26 ft. 3 in. at a height of 6 in. above rail level. The roof is semicircular, and the work is drained by a culvert running principally along one side of the tunnel wall. Of course a number of different types of construction were adopted, varying with the nature of material passed through. In disintegrated rock there is a continuous lining of masonry with an invert and a culvert running along the centre, but we believe only very short lengths of this type of construction have been found necessary. Along the whole length of the tunnel, on each side and opposite to each other, recesses 6 ft. 6 in. high, 39 in. deep, and 6 ft. 6 in. wide, are formed at intervals of 328 ft. At each kilometre these recesses are replaced by larger vaults, and at three points in the length large chambers are excavated in the rock at right angles to the axis of the tunnel.

Granitic and micaceous schist, with hornblende and small quantities of dolomite, form the rocks through which the tunnel was excavated, and the formation which approached the vertical towards the centre of its length, fell north and south with increasing divergence. The following is an approximate statement of the stratification as prepared by Professor Fritsch, of Frankfort:

	Metres.
Granitic schist, more or less homogeneous	2200
Gneiss, more or less schistous	450
Crystalline limestone	350
Micaceous schist	1300
Gneiss, rich in mica	6600
Mica schist with hornblende	1600
Gneiss, more or less schistous	270
Mica schist, with veins of quartz	800
Hornblende schist	1250
Dolomite, gypsum, &c.	100

Only a very short length of granite was encountered, and that by the north end of the tunnel passing through one of the Finsteraarhorn granite spurs. As the work proceeded the deductions of Professor Fritsch, who had reported on the subject for the Swiss Geological Commission, were found to be very near the truth, as also were those of M. Giordano, then Inspector of the Royal Corps of Mines of Italy, and who had reported independently on the probable formation along the axis of the tunnel.

The contract for the tunnel was let by the Swiss Government to M. L. Fabre on August 9th, 1872. Negotiations had for a long time been in progress between Switzerland, Italy, and Germany upon this subject, and an international treaty between the two

first-named powers was signed in October, 1869, Germany subsequently adding its support in 1871. This agreement formed the basis for the political and financial details of the scheme. The international subvention was fixed at 85,000,000 francs, of which Switzerland contributed 45, Germany 20, and Italy 45 millions. Subsequent experience showed how far the first complete estimate fell short of the actual outlay, and early in 1876 it began to be realised that instead of 187,000,000 francs—the original computed sum for the whole work, railways and tunnel—the undertaking would cost at least 289 millions. This enormous excess naturally involved the undertaking in the gravest financial difficulties, which for a long time threatened at least a prolonged stoppage of the undertaking, but after many efforts these difficulties were surmounted, and the work as we have seen brought to a fortunate issue.

The contract signed by M. Favre was based upon the following schedule of prices:

			£	£
1. Straight length of tunnel at north end	158.6	lin. yds. at	54.4 =	8,631
2. Excavation of tunnel	16,295	„ „	101.6 =	1,655,500
3. Ballast, &c.	16,295	„ „	1.6s. =	13,008
4. Laying rails	32,590	„ „	2.9s. =	4,730
5. Ashlar masonry	52,320	c. yds. „	2.27 =	119,050
6. Stone facing	71,760	sq. yds. „	13.38 =	47,620
7. Ordinary masonry	39,240	c. yds. „	1.21 =	47,620
8. Masonry for niches				786
Total				1,896,945

As may be readily imagined, the plant required for the execution of this great work was very extensive, not only at each end of the tunnel but also that required for excavation and removing the débris as the headings and subsequent enlargement progressed.

The shops at Goeschenen were commenced at the beginning of 1873 by the construction of a building to receive the provisional compressors which were at work by the end of March. The power for working these compressors was obtained from the River Reuss, which was diverted so as to obtain a fall of 260 ft. This was of itself a work of no small magnitude, involving the construction of a dam, large settling and filtering reservoirs, and an aqueduct of masonry and wrought-iron mains 33.5 in. in diameter. Near the works this main was divided into branches and led to the turbine house. During 1873 this work was completed, the building for turbines and compressors was erected, and several of them were in operation. During the three succeeding years more turbines and air compressors were added, and the various shops, especially those for repairing the drills, were enlarged. The power for driving these

shops was obtained from a separate main led off from the Reuss to a turbine. Workmens' dwellings, stables, stores, dynamite magazines, &c., continued to increase, and in 1874 locomotives were employed to remove the débris of the excavation. In 1875 over 5000 yards of 46 in. ventilating main had been laid in the tunnel, and the compressed air locomotives were at work. The works at Airolo were very similar, the requirements and the means of supplying these being much alike in both cases. In 1877 there were twenty-three air compressors at work at each end of the tunnel delivering 42,360 cubic feet per hour at a pressure of 105 lb. per square inch into the workings. Nineteen of these compressors were chiefly employed in supplying power for the rock drills, the remainder worked the locomotives referred to above.

Several systems of rock drills were employed, amongst others the Ferroux, Mackean, Turettini, and Dubois-François, and when the works were in full operation forty drills could be kept going at each end, seven in the front of the small heading, and the remainder working at the enlargement. The consumption of air by these drills collectively was equivalent to 4200 cubic feet per minute at atmospheric pressure, or 1000 ft. less than the compressors could furnish.

But little progress was made in the work of boring during 1872, and it was carried on by hand for the first six months, the advancement at the north end through the granite being much slower than at the south end, where the material attacked chiefly consisted of mica-schist, intersected, however, with abundant water-bearing fissures. About six months after the commencement of the tunnel the rock drills were put in operation, and the rate of advance was consequently much more rapid. The heading was driven at a level corresponding to the upper portion of the tunnel, and the lateral and downward enlargement was then proceeded with. At the south end a plentiful discharge of water was encountered at the commencement of the work, but little inconvenience was felt for some time after a distance of 1600 yards had been reached. Previous to reaching this point, however, the discharge had been as much as 3000 gallons per minute, projected from a great number of fissures that filled the gallery with jets of great size and velocity, which were also often of high temperature. Between 2500 yards and 4500 yards of distance, again, water-bearing rocks, chiefly laminated mica-schists, were passed, and here again the discharge sometimes exceeded 3000 gallons per minute. The average size of the heading was 8 ft. 2½ in. square, which gave a face area of 64.7 square feet. When driving through hard rock about 25 holes were drilled in the face in rows of five each. The three central holes formed a triangle, and were bored to converge until at the bottom they were only 4 in. apart, the distance at the surface

being 16 in. The holes near the boundary of the heading diverged, and the others were drilled perpendicular to the face of the rock. All the holes were bored taper, a succession of drills being employed varying in diameter from 1.9 in. to 1.25 in.; the average depth ranged from 3.5 ft. to 4 ft. As soon as the work of drilling for a blast was completed the drill battery was drawn back for a distance of 100 yards, and a wagon was stationed in front of it to protect it against fragments of rock. The blast was performed in three stages, the central holes being first filled with cartridges 28.3 oz. each, and fired, then all the remaining holes, except those in the bottom row, were charged with 17.5 oz. cartridges, and fired successively by means of fuses of different lengths. Finally, the bottom row of holes was charged and fired. About 490 oz. of dynamite were used at each blast, and the quantity of rock broken down was about 8.3 cubic yards. This mode of procedure of course applied to the hard rock only, especially to that met with at the Goeschenen mouth. In the softer material fewer holes and smaller charges sufficed.

The following Table summarises the total progress since the beginning of the work to the end of 1878:

Year.	Hand Work.		Machine Work.		Total.	Work to be Done.
	North End.	South End.	North End.	South End.		
	yards.	yards.	yards.	yards.	yards.	yards.
1872	20.7	112.2	. . . . .	. . . . .	132.9	16,162.1
1873	76.3	128.5	559.4	412.1	1176.3	14,985.8
1874	. . . . .	. . . . .	1134.1	817.4	1951.5	13,034.3
1875	21	. . . . .	1262.3	1378.1	2635.4	10,398.9
1876	50.3	. . . . .	1049.6	1116.1	2165.7	8,233.2
1877	. . . . .	. . . . .	1345.7	1087.2	2432.9	5,800.3
1878	. . . . .	. . . . .	1400	1300	2700	3,100.3

From the above Table it will be seen that the work made steady and accelerating progress from its commencement, in spite of the great and unforeseen physical obstacles, and the even more serious and besetting financial difficulties which had to be encountered.

As an example of the results obtained, we may summarise the work done during the three months ending with September, 1878. These results are given in the following Table.

Between 3000 and 4000 labourers were employed upon the works; thus in August, 1875, at the north end, the maximum number was 1902, and at the south end 1984. The average number of

Results of Working in Tunnel for Three Months ending September, 1878.

	North End.	South End.	Total.
Machines employed	Ferroux	Mackean.	
Gross section of gallery, square yards	8.13	7.48	7.80
Monthly advance, yards	115.6	154.1	269.7
Average advance per day	3.76	5.43	9.19
Maximum advance in one day	5.72	7.00	12.72
Number of shifts	81	107	188
„ hours work	728 hr. 40 min.	678 hr. 23 min.	1407 hr. 3 min.
Time lost	9 hr. 40 min.	55 hr. 40 min.	65 hr. 20 min.
Time occupied in drilling	389 hr. 10 min.	332 hr. 20 min.	721 hr. 30 min.
„ „ blasting and clearing	332 hr. 50 min.	346 hr. 30 min.	679 hr. 20 min.
Average time occupied per yard	41.5 min.	33.3 min.	37.4 min.
„ „ for one blast	5 hr. 11 min.	3 hr. 10 min.	4 hr. 10 min.
„ „ in blasting and clearing	4 hr. 9 min.	3 hr. 15 min.	3 hr. 42 min.
„ between blasts	9 hr. 20 min.	6 hr. 25 min.	7 hr. 53 min.
Number of holes drilled	1679	1852	3531
Average of holes per blast	20.7	17.39	19.04
Total length drilled in yards	2069.3	2761.0	4740.3
Average length per blast yards	30.29	25.01	27.65
„ „ per hole yards	1.46	1.43	1.44
Number of shifts of machines	324	496	820
Average number „ on carriage	4	4.62	4.31
Total „ „ repaired	25	47	72
„ „ of drills repaired	5993	5085	11,078
Average pressure in atmospheres of compressed air	3.62	3.51	3.56
„ temperature when drilling	74.7 deg.	77.2 deg.	76.0 deg.
„ „ after blasting	79.7 deg.	84.2 deg.	82.0 deg.
Consumption of dynamite per day in heading	171.6 lb.	200.6 lb.	372.2 lb.
„ „ rest of tunnel	330.0 lb.	352.4 lb.	682.4 lb.
„ „ yard of heading	46 lb.	39 lb.	85 lb.

hands during the three months ending September, 1878, was at the north end 1264, and at the south end 1819. For the month of September of the same year the distribution of labour was as follows:

	In the Tunnel.	Outside.	Total.
North end	918	341	1259
South end	1199	582	1781
	2117	923	3040

One great difficulty which was encountered during the undertaking was the high temperature in the workings, increased of course by the frequent blastings. The heat on the south side was for the most part considerably higher than at the north, owing probably to the mountain being higher over the works on the south. The highest recorded temperature to the end of 1878 was 85 deg. Fahr., but we believe that subsequently this was very considerably surpassed, and was one of the most serious difficulties in the way of completion of the work. The free circulation of air resulting from the junction of the two headings will do much to remove this difficulty. According to the terms of the contract, the tunnel was to be completed in October of the present year.

ENGINEERING, *March 5, 1880.*

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14. CANALS.*

CANALS may be divided into three classes:

1. *Level Canals* or *Ditch Canals*[1], consisting of one *reach* or *pond*[2] which is at the same level[3] throughout.

2. *Lateral Canals*[4], which connect two places in the same valley, and in which, therefore, there is no summit level[5], the fall[6] taking place in one direction only. A lateral canal is divided into a series of level reaches or ponds, connected by sudden changes of level, at which there are either single *locks* or *flights of locks*[7], or some other means of transferring boats from one level to another. The *lift*[8] of a single lock ranges from 2 feet to 12 feet. In fixing the lengths of reaches and the positions of the locks, the engineer should have regard to the fact that economy of water[9] is promoted by distributing a given fall amongst single locks with reaches between them, rather than concentrating the whole fall at one flight of locks.

[1] Horizontaler Kanal. [2] Kanalhaltung. [3] Niveau, Wasserspiegel. [4] Seitenkanal. [5] Wasserscheide. [6] Gefälle. [7] gekuppelte Schleuse. [8] Hubhöhe. [9] Wassererspariss.

* S. *Technical Vocabulary*, ch. 50.

3. *Canals with Summits*[5] have to be laid out with a view to economy of works at the passes between one valley and another, and with a view also to the obtaining of sufficient supplies of water[10] at the summit reaches.[11]

Construction of a Canal.—The least expensive parts of a canal are those in which the upper part of the water-way is contained between two embankments[12], and the lower part in a cutting[13], the earth dug from which, together with that dug from the side-drains[14] at the foot of the outer slopes[15], is just sufficient to form the embankments. All canal embankments should be formed and rammed in thin layers.[16] The width of the embankment which carries the towing-path[17] is usually about 12 feet at the top[18]; that of the opposite embankment at least 4 feet, and sometimes 6 feet. Each embankment has a vertical puddle wall[19] in its centre from 2 to 3 feet thick. The surface of the towing-path is usually about 2 feet above the water-level. It is made to slope slightly in a direction away from the canal, in order to give a better foothold for the horses, as they draw in an oblique direction. The slopes are to be pitched[20] with dry stone from 6 to 9 inches thick. Occasionally it may be necessary to line[21] a canal with concrete[22], or to face[23] the sides with rows of sheet-piling[24], in order to retain the water. Natural water-courses[25] are to be carried below the canal by means of bridges and culverts[26], and, if necessary, by means of inverted siphons[27] of masonry[28] or iron. Each reach of a canal should be provided with waste-weirs[29] in suitable positions, to prevent its waters from rising to too high a level, also with sluices[30], through which it may be wholly emptied for purposes of repair; and in a reach longer than two miles, or thereabouts, there may be stop-gates[31] at intervals, so that one division of the reach may be emptied at a time, if necessary. As to the dimensions of water-way, the following are the general rules:

Least Breadth at Bottom[32] $= 2 \times$ greatest breadth of a boat.

Least Depth of Water $= 1\frac{1}{2}$ foot $+$ greatest draught[33] of boat.

Least Area of Water-way $= 6 \times$ greatest midship section[34] of a boat.

Canal Aqueducts and Fixed Bridges.—A canal aqueduct[35] is a bridge supporting a water channel. The trough or channel[36], for economy's sake, is usually made wide enough for one boat only; its bottom is flat, its sides vertical or slightly battering.[37] The principle of the suspension bridge[38] is peculiarly well adapted to aqueducts.

[10] Wasserversorgung, Wasserzufluss. [11] Teilhaltung. [12] Damm, s. Nr. 2. [13] Einschnitt, s. Nr. 2. [14] Seitengraben. [15] Böschung. [16] s. Nr. 2, 93. [17] Leinpfad. [18] Krone. [19] Lehmschlagmauer. [20] abpflastern. [21] füttern, auskleiden. [22] s. Teil I, Nr. 21. [23] verkleiden. [24] Spundwand, s. Nr. 17. [25] Wasserlauf. [26] Durchlass, Dohle. [27] umgekehrter Heber. [28] Mauerwerk. [29] Leerlauf. [30] Schütze. [31] Abschlussthor. [32] Sohle. [33] Tiefgang. [34] Mittelquerschnitt. [35] Kanal-Aquäduct. [36] Rinne. [37] geböscht. [38] Hängebrücke.

Fixed bridges[39] over canals require no special explanation. Sometimes the archway[40] admits the water-channel alone, while the towing-path ascends to the approach[41] of the bridge and descends again, the tow-rope[42] being cast loose while the horse passes over.

In *tunnels*[43] for canals the towing-path is sometimes dispensed with, the boats being pushed through by means of poles, or by the hands and feet of the boatmen, with the aid of notches in the brick-work, or by means of the various methods of steam propulsion.[44]

Movable bridges.[45]—Movable bridges across a canal near its water-level are made of timber or iron, and are capable of being opened so as to leave the navigation clear, and closed so as to form a passage for a road or railway by one or other of five kinds of movement, viz., 1. By turning[46] about a horizontal axis; 2. By turning about a vertical axis; 3. By rolling horizontally; 4. By lifting[47] vertically; 5. By floating[48] in the canal.

A bridge which turns about a horizontal axis near an end of its span[47] is called a *draw-bridge.*[50] It is opened by being raised into a vertical position by means of a pinion[51] driving a toothed sector.[52] It is best suited for small spans.

A bridge which turns about a vertical axis is called a *swing-bridge.*[53] Its principal parts are as follows:—A pier[54] of masonry or iron, supporting a circular base-plate[55] of a diameter equal, or nearly equal, to the breadth of the bridge; that base-plate has a pivot[56] in the centre, and a circular race or track[57] for rollers[58] round the circumference, as in a railway turntable[59]: A roller frame[60] turning about the central pivot, with a set of conical rollers resting on the race: A circular revolving platform[61] resting on the pivot and rollers: A toothed arc[62] fixed to the revolving platform, with suitable wheel-work for giving it motion: A set of parallel girders[63], resting on and fastened to the revolving platform, of the strength and stiffness required by the principles already stated, and supporting a roadway.[64] The ends of the superstructure[65] are bounded by arcs of circles, described about the axis of motion, and the ends of the roadway of the approaches must be formed to fit them.

A *rolling bridge*[66] has a strong frame, supported by wheels upon a line of rails[67], and having an overhanging portion sufficient to span[68] the water-way. When closed, by being rolled forward, the rolling frame leaves a gap[69] between its platform and that of one of the approaches, which gap is filled by rolling in another

[39] feste Brücke. [40] Wölbung. [41] Zufahrt. [42] Zugleine. [43] s. Nr. 11. [44] Dampfbeförderung. [45] bewegliche Brücke. [46] Drehen. [47] Heben. [48] Schwimmen. [49] Spannweite. [50] Zugbrücke. [51] Getriebe. [52] gezahnter Kreisausschnitt, Zahnsektor, s. T. II, Nr. 6, 14. [53] Drehbrücke. [54] Pfeiler. [55] Grundplatte. [56] Zapfen, Drehzapfen. [57] Laufkranz, Schienenring. [58] Rollen, Laufrollen. [59] Drehscheibe. [60] Rahmen. [61] Bedielung, Boden. [62] Zahnbogen. [63] Träger. [64] Fahrbahn. [65] Ueberbau, Oberbau. [66] Schiebebrücke. [67] Schienengleis. [68] überspannen. [69] Lücke.

rolling frame that moves sideways. The latter rolling frame is rolled out of the way before opening the bridge.

A *lifting bridge*[70] is hung by the four corners to four chains, which pass over pulleys[71], and have counterpoises[72] at their other ends.

A *floating swing-bridge* rests on a caisson[73] or pontoon[74]: it is opened and closed by means of chains and windlasses[75], and, when open, lies in a recess[76] in the side of the canal made to receive it. The pontoon, being made of sheet iron[77], is so designed as to act as a tubular girder[78] when the bridge is closed.

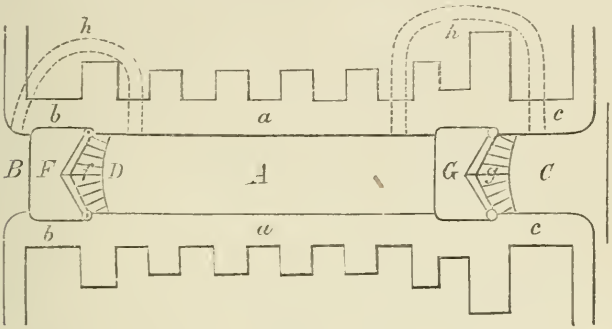

Fig. 5.

Canal Locks.[79]—Fig. 5 shows the general arrangement of the parts of a canal lock. The clear length of the *lock-chamber*[81] *(A)* should be at least equal to that of the longest vessel used on the canal, including the rudder; its clear[80] breadth, one foot more than the greatest breadth of a vessel; its greatest depth of water should be $= 1\frac{1}{2}$ foot + greatest draught[33] of a vessel + lift[8] of the lock. Its depth from the cope[18] of the side walls to the bottom may be about 2 feet more. The *side walls*[82] *(a a)* and *floor*[83], or *invert*, are recessed to admit of the opening of the *tail-gates.*[91] The floor is level with the bottom of the lower of the two ponds[2] to be connected. *B* is the *head-bay*[84] with its side-walls and floor, which are recessed to admit of the opening of the *head-gates*[85]: the floor is level with the bottom up the upper pond. *C*, the *tail-bay*[86]; the side-walls end in curved wings: the floor in a dry stone pitching[87] or *apron.*[88] *D*, the *lift-wall*[89], which is usually built like a horizontal arch. *F*, the *head-gates*, whose lower edges, when shut, press against the *head mitre-sill*,[90] *f*. *G*, the *tail-gates*[91], whose lower edges, when shut, press against the *tail mitre-sill*, *g*. The

[70] Hubbrücke. [71] Rolle, s. Teil II, Nr. 7. [72] Gegengewicht. [73] Caisson, Kasten. [74] Ponton. [75] Winde. [76] Nische. [77] Eisenblech. [78] Röhrenträger. [79] Schleuse, Kammerschleuse. [80] licht. [81] Schleusenkammer. [82] Seitenwand, Schleusenwand. [83] Boden. [84] Oberhaupt. [85] Oberthor. [86] Unterhaupt. [87] Abpflasterung. [88] Hinterboden, Bodenbefestigung. [89] Fallwand, Fallmauer. [90] Drempel, Schlagschwelle. [91] Unterhaupt.

older locks are filled and emptied through *sluices*[30] in their head and tail-gates; but now the more general practice is to use for that purpose inlet and outlet passages[92] with slide-valves.[93] These passages may either be culverts contained in the thickness of the masonry, or iron pipes in such positions as those marked *h*, *h*. The cylindrical recesses in which the gates are hinged are called the *hollow quoins*.[94]

The following parts of a lock are usually of ashlar[95]:—The quoins[96], hollow quoins, cope[97], recesses for the gates (or "gate-chambers"[18]) and mitre-sills. The mitre-sills are sometimes faced with wood, to enable them the better to withstand the blows which they receive from the gates, and to make a tighter[99] joint. The floor of the lock is sometimes made of cast iron.

The *gates* are made of timber or of iron, and each of them consists of the following principal parts:—The *heel post*[100], about the axis of which the gate turns. This post is cylindrical on the side next the hollow quoins, which it exactly fits when the gate is shut. It is advisable to make it slightly eccentric[101], so that when the gate is opened, it may cease to rub on the hollow quoins. At its lower end it rests on a pivot, and its upper end turns in a circular collar, which is strongly anchored[102] back to the masonry of the side walls: The *mitre-post*[103], forming the outer edge of the frame of the gate, which, when the gate is shut, abuts[104] against and makes a tight joint[105] with the mitre-post of the opposite leaf:[106] The cross-pieces[107] which extend horizontally between the heel-post and mitre-post: The *cleading*[108] or covering, which may consist of timber planking[109] or iron plates; when it consists of planks, they run either vertically or diagonally: The *diagonal bracing*[110], which, in its simplest form, may consist either of a timber strut[111] extending from the bottom of the heel-post to the top of the mitre-post, or of an iron tie-bar[112] extending from the top of the heel-post to the bottom of the mitre-post. The gates are often provided with *balance-bars*.[113] A balance-bar is bolted[114] to the top of the mitre-post, slopes slightly upwards, and crosses over the top of the heel-post, which is mortised[115] into it, and has a long and heavy overhanging end, which acts as a counterpoise to bring the centre of gravity[116] of the gate near the heel-post, and as a lever[117] to open and shut it by. Sometimes the balance-bar is dispensed with, and each gate has one or more *rollers*[58] under its lowest cross-bar[118], to assist the pivot in supporting its weight. Each of those rollers runs upon a quadrantal iron rail on the floor of the gate-chamber. This mode

[92] Ein- und Auslasskanäle, Umläufe. [93] Schieber, s. Teil II, Nr. 28. [94] Wendenische, Ansehlag. [95] Quaderstein. [96] Eckstein. [97] Mauerabdeckung. [98] Thorkammer. [99] dicht. [100] Wendesäule. [101] excentrisch, s. Teil II, Nr. 7, 20. [102] verankern. [103] Schlag-, Anschlag-, Stemmsäule. [104] (zusammen)stossen. [105] Fuge. [106] Thorflügel. [107] Riegel. [108] Verschalung. [109] Dielen. [110] Diagonalverstrebung, Abspreizung mit Kreuzspreizung. [111] Strebe, Spreize. [112] Zugstange. [113] Wagbalken. [114] festbolzen. [115] verzapfen. [116] Schwerpunkt. [117] Hebel. [118] Unterriegel, Unterrahmen.

of construction is almost always adopted in large and heavy gates that require chains and windlasses to open and shut them.

Inclined planes.[119]—To save the time and water expended in shifting boats from one level to another by means of locks, *inclined planes* are used on some canals.

Water supply[120] *of Canals.*—Canals are supplied with water from gathering-grounds, springs, rivers, and wells, by the aid of reservoirs and conduits.[121] The *demand* for water[122] depends upon the waste of water by leakage[123] of the channel, repairs and evaporation[124]; upon the current[125] from the higher towards the lower reaches, produced by leakage at the lock gates; and upon the lockage, or expenditure of water in passing boats from one level to another. Water may be saved at flights of locks[7] by the aid of *side-ponds*[126], sometimes called *lateral reservoirs.* The use of a side pond is to keep for future use a certain portion of the water discharged from a lock, when the locks below it in the flight are full, which water would otherwise be wholly discharged into the lower reach.

RANKINE, *A Manual of Civil Engineering.*

15. THE ERIE CANAL.

THE ERIE CANAL was commenced in 1817, and completed in 1825. The main line leading from Albany, on the Hudson, to Buffalo, on Lake Erie, measures 363 miles in length, and cost about $ 7,200,000. The Champlain, Oswego, Chemung, Cayuga, and Crooked Lake Canals, and some others, join the main line, and, including these branch canals, it measures 543 miles in length, and cost upwards of $ 11,500,000. This canal was originally 40 feet in breadth at the water-line, 28 feet at the bottom, and 4 feet in depth. Its dimensions proved too small for the extensive trade which it had to support, and the depth was increased to 7 feet, and the extreme breadth of the canal to 60 feet. There are 84 locks on the main line. These locks, originally 90 feet in length and 15 in breadth, and with an average lift of 8 feet 2 inches, have since been much enlarged. The total rise and fall is 692 feet. The tow-path is elevated 4 feet above the level of the water, and is 10 feet in breadth. At Lockport the canal descends 60 feet by means of 5 locks excavated in solid rock, and afterwards proceeds on a uniform level for a distance of 63 miles

[119] geneigte Ebene. [120] Wasserversorgung, Speisung. [121] Leitung. [122] Wasserbedarf. [123] Lecken, Undichtigkeit. [124] Verdunstung. [125] Abfluss. [126] Sparteich.

to Genesee River, over which it is carried on an aqueduct having 9 arches of 50 feet span each. Eight and a half miles from this point it passes over the Cayuga marsh, on an embankment 2 miles in length, and in some places 70 feet in height. At Syracuse, the "long level" commences, which extends for a distance of 69½ miles to Frankfort, without an intervening lock. After leaving Frankfort, the canal crosses the river Mohawk, first by an aqueduct 748 feet in length, supported on 16 piers, elevated 25 feet above the surface of the river, and afterwards by another aqueduct 1188 feet in length, and emerges into the Hudson at Albany.

KNIGHT'S *American Mechanical Dictionary.*

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16. DREDGING-MACHINES USED IN EXCAVATING THE SUEZ CANAL.*

AMONG the numerous obstacles which were encountered, none were half so formidable as effecting a channel through Lake Menzaleh, which extended 21 miles from Port Said to Kantara. The lake fishermen had to throw up the liquid mud with their hands, so as to form a kind of dyke; and had it not been for the powerful Egyptian sun, which dried up the mud so exposed within a few hours, the task would have been hopeless, as there is no known mechanical appliance to overcome an obstacle of this sort. When something like an opening had been made, and the water began to flow in, rafts were constructed, and in these the men slept under tents made of mats. When the men had scooped out with their hands a passage of sufficient dimensions, *dredging machines* were introduced, and they returned to their original occupation of fishermen. Bit by bit this trench was widened, until it reached the dimensions of 330 feet wide, and 26 feet deep. It was on these parts that *dredgers with long shoots* were used. The shoot is 220 feet long by 28 feet wide, and drawing 1½ feet of water, with 35 horse power engines. The dredgers with long shoots dispensed with the expensive mode of disposing of the débris of the dredgers into hopper barges, and then conveying them to be emptied. These dredgers have each excavated from 300,000 to 350,000 metres per annum, and some have done 3000 cubic metres each in a day.

* *Dredging* Baggern, *to dredge* baggern, *to excavate* ausheben, ausgraben, *hand-drag* Handbagger, Baggerhaken, *spoon (and bag)* Baggerlöffel, Sackschaufel, *scoop* Wasserschaufel, Schöpfkelle, *dredger, dredging-machine* Bagger, Baggermaschine, *bucket* Eimer, *bucket-chain* Eimerkette, *inclined plane, ladder* Schlitten, *drum, tumbler* Trommel, *hopper-barge* Schlammboot, *dredgers with long shoots* (frz. *dragues à longs couloirs*) Bagger mit geneigten Ausflussrinnen, *steam-dredger* Dampfbagger.

At the southern extremity of Lake Menzaleh, the canal quits the region of stagnant waters, and we come to Kantara, the name for bridge. This was formerly a town of importance, rivalling Pelusium, Tanis, and Rameses, and other flourishing cities on the delta of the Nile. From Kantara to El Ferdane the canal passes through an undulating country, where several elevations occur, and the dredgers with long shoots were of no use here. It required an apparatus fitted to enable the silt to be thrown over these elevations; and these necessarily led to the invention of a totally different mechanical appliance, which goes by the name of the "*élevateur*". The dredger excavated the canal, and deposited the contents in a floating barge placed near it. This barge has six loose compartments. When these compartments or boxes have been filled, the barge quits the dredger and goes alongside the elevator. The elevator is a kind of railed bridge, starting from the level of the water, and ascending to the height of 46 feet. This aerial railway is supported by two iron posts, the one resting on a barge and the other on the banks of the canal; the whole structure being joined together by solid cross-beams. The full boxes are raised out of the barge by machinery, and travel along the railed bridge till the extreme end is reached, at a height of 56 feet, and then discharge their contents on the banks, returning empty to be again refilled as before. Eighteen of these elevators, with 700 boxes, have been employed on the works in those parts of the canal where the banks were too elevated to allow the use of the long "couloir" and where the distance from the sea and lakes was too great for the hopper barges to be used with advantage and economy.

Lake Ballah terminates at El Ferdane, where the desert commences. This land is determined by a ridge of sand about 3 feet above water, a slight depression follows, the undulations become more marked, and extend along a distance of six miles. Then a sudden rise occurs, and we find ourselves in face of a mound 53 feet high and 600 feet in length. After that comes the depression, a sort of a valley descending 13 feet, and the Seuil d'El Guisr presents a veritable rampart of 61 feet high. It was necessary that the maritime canal should pass through this cutting, in order to allow the waters of the Mediterranean to flow in the vast depression which follows, viz., Lake Temsah. At this point all our efforts had to be concentrated; this barrier had to be removed..... The Fellaheens having completed their task, sufficient depth had been obtained for the dredgers to take their place. But here a new difficulty arose. How to dredge a channel, and then to get the earth removed out of this hollow? The difficulty was overcome by the invention of the excavator or dry dredger. A locomotive engine on two rails, running parallel with the canal, formed the motive power. From the locomotive descended a chain

with iron buckets, which scooped up the earth as it was drawn up the slope, and then emptied into wagons. When a sufficient number were filled, these waggons, in their turn, were drawn up to the summit of the embankment, along a succession of tramways winding at sharp angles till they reached the top.

THE ARTIZAN.

17. PILES.*

BEARING PILES[1] act as pillars, each supporting its share of the weight of the building. They may either be driven through the soft stratum until they reach a firm stratum and penetrate a short distance into it; or, if that be impracticable, they may be supported wholly by the friction[2] of the soft stratum. It appears from practical examples that the limits of the safe load on piles are as follows:— For piles driven till they reach the firm ground, 1000 lbs. per square inch of area of head[3]; for piles standing in soft ground by friction, 200 lbs. per square inch of area of head.

The diameters[4] of long piles range from 9 inches to 18 inches, and should never be less than 1-20th of the length. Their distance from centre to centre averages about 3 feet, and is seldom less than $2\frac{1}{2}$ feet. The best material for them is elm, which should be chosen as straight-grained as possible. The bark should be removed, and knots or rough projections smoothed off.

Piles should be driven with the butt[5] or natural lower end of the timber downwards. It is roughly sharpened to a point whose length is from $1\frac{1}{2}$ times to twice its diameter; and should stones or other hard materials occur in the strata to be pierced, the point must be fitted with a *shoe*[6] of cast or wrought iron, fastened on with spikes.[7] The weight of these shoes averages about 1-100th part of that of the piles. To prevent the head of a pile from being split or bruised by the blows of the *ram*[8] used in driving it, it is bound with a wrought iron hoop.[9]

Pile-driving engines[10] are of various kinds. The simplest is the "*ringing engine*"[11], in which the *ram*, weighing about 800 lbs., and moving between timber *guides*[12], is attached to one end of a rope

[1] *Pile* (lat. *pila*) Haufen, Kugelhaufen, Gewehrpyramide, (Holzkohlen-)Meiler, Scheiterhaufen, (grosses) Gebäude, (Voltaische) Säule, Packet (Eisenfabr., s. Nr. 2), Revers oder Rückseite (einer Münze), Pfahl; (lat. *pilum*) Pfeilspitze; (lat. *pilus*) Pole, Flor (von Geweben). *Bearing pile* Tragpfahl, Grundpfahl. [2] Reibung, s. Nr. 8, 16. [3] Kopffläche. [4] Durchmesser. [5] Wurzelende. [6] Schuh. [7] Hakennagel. [8] Rammbär. [9] Ring. [10] Rammmaschine. [11] Zugramme. [12] Läuferrute.

* S. *Technical Vocabulary*, ch. 50.

which passes over a pulley.[13] The other end of the rope branches out into a number of smaller ropes[14], each held by a man, in the proportion of one man for each 40 lbs. weight of the ram, or thereabouts. The men, pulling all together, lift the ram 3 or 4 feet, and on a given signal, let go all at once, so as to drop it on the head of the pile. It is found that they work most effectively, when, after 3 or 4 minutes of exertion, they have an interval of rest; and under these circumstances they can give about 4,000 or 5,000 blows per day.

In the "*monkey engine*"[15], the ram, weighing about 400 lbs., and held by a staple in a pair of tongs, is drawn up 10 feet, 15 feet, or higher if necessary, by means of a windlass[16]; at the top of the lift the handles of the tongs come into contact with two inclined planes[17] which cause them to let the ram fall; the tongs are then lowered, and have jaws so shaped that on reaching the staple at the top of the ram they lay hold of it again. The windlass may be driven by men, horses, or steam power.

The steam hammer[18] is sometimes used for driving piles; and also an engine somewhat on the same principle, in which the ram is lifted by the pressure of compressed air.[19] In such machines rams of great weight are sometimes used, such as 1 ton, or a ton and a-half.*

Piles may be driven in a direction either vertical or raking[20], according to the position of the guides between which the ram slides. That direction should be parallel to that of the pressure which they are to resist.

When the head of a pile is to be driven below the reach of the stroke of the ram, the blow is transmitted from the ram to the pile by means of an intermediate short post of timber called a "*punch*", or "*dolly*".[21]

According to some of the best authorities, the test of a pile's having been sufficiently driven is, that it shall not be driven more than one fifth of an inch by thirty blows of a ram weighing 800 lbs. and falling 5 feet at each blow; that is to say, by a series of blows whose total mechanical energy amounts to $30 \times 800 \times 5 = 120{,}000$ foot-pounds.

Piles are *drawn*[22], if required, by means of the hydraulic press.[23]

[13] Rolle, s. Nr. 7. [14] Zugleine. [15] Kunstramme; *steam pile-driver* Dampframme. [16] Winde. [17] schiefe Ebene. [18] Dampfhammer, s. Teil II, Nr. 15. [19] comprimirte Luft. [20] schief. [21] Rammknecht. [22] herausziehen. [23] hydraulische Presse, s. Teil I, Nr. 3.

* Some conception of the rapidity with which piles are driven by a *steam pile-driver* may be formed, when it is stated that a pile measuring 60 feet in length and 14 inches square can be driven 45 feet into stiff soil, down to the rock below, in four minutes.—In Shaw's pile-driver, the monkey is sustained at its highest elevation by means of a ratchet and pawl, while a cartridge and cap are placed in a recess in the head of the pile. The pawl being withdrawn, the monkey falls upon and explodes the cartridge. The force of the explosion raises the monkey to the height from which it fell, where it is automatically arrested by the detent arrangement. KNIGHT.

After the driving of a set of piles has been completed, their heads are to be sawn off to the height required for the support of the platform. The soft ground round the tops of the piles is then to be scooped out to a depth which in ordinary cases ranges from 3 to 5 feet, and the space filled with hydraulic concrete, laid in layers not exceeding 1 foot deep.

The platform supported by the piles consists of a grating[24] of beams of 10 or 12 inches square[25], called *string-pieces*[26] and *cross-pieces*[27], half-notched into each other over the heads of the piles, to which they are fixed by treenails[28], and covered with planking[29] 3 or 4 inches thick. The spaces between the beams of the grating are to be filled with hydraulic concrete.[30] The beams on the top of the outermost rows of piles are usually made so deep that their upper surfaces are flush[31] with that of the planking, which is *rabbeted*[32] into them; that is, sunk in a groove. Those beams are in this case called the *capping*.[33]

Piles may be driven into rock by first jumping[34] holes in it of a little less diameter than the piles.

For cast iron piles, the best form is that of a tube. To prevent their being broken by the blows of the ram in driving them, a timber punch[21] is interposed between the head of the ram and the pile. The best mode, however, of driving them, is by aid of the screw.

Screw piles[35], the invention of Mr. Alexander Mitchell, are piles which are screwed into the stratum in which they are to stand. The pile may be either of timber or iron. The screw blade, which is fixed on at the foot of the pile, is usually of cast iron, and seldom makes more than a single turn.[36] Its diameter is from twice to eight times that of the shaft of the pile, and its pitch[37] from one-half to one-fourth of its diameter. The best mode of driving screw piles is to apply the power of men or of animals, walking on a temporary platform, directly to levers[38] radiating from the heads of the piles.

Sheet piles[39] are flat piles, which, being driven successively edge to edge, form a vertical or nearly vertical sheet[40], for the purpose of preventing the undermining action of water. They may be made either of timber or of iron.

Timber sheet piles are planks having a projection or feather along one edge, and a corresponding groove[41] along the opposite edge. They are of any breadth that can readily be procured, and from $2\frac{1}{2}$ to 10 inches thick, and are sharpened at the lower end to an edge, which, in stony ground, may be shod with sheet-iron.

[24] Rost. [25] im Gevierte. [26] Langschwellen. [27] Querschwelle. [28] Holznagel. [29] Bohlen, Dielen. [30] hydraulischer Steinmörtel, s. Teil I, Nr. 21, 22. [31] bündig. [32] (in einem Falz) einlassen. [33] Kappen, Kapphölzer. [34] bohren (mit dem Stossbohrer, *jumper*). [35] Schraubenpfahl. [36] Windung. [37] Ganghöhe, s. Teil II, Nr. 5. [38] Hebel. [39] Spundpfahl. [40] Spundwand. [41] Rinne. Nut.

When a space is to be enclosed with sheet-piling[40], a range of *guide-piles*[42] is first driven, being long rectangular piles at regular intervals apart of from 6 to 10 feet: these are driven to the same depth as bearing-piles. To the opposite sides of these, near the top, are notched or bolted a pair of parallel *string-pieces* or *wales*[43]: these are horizontal beams, from 5 to 10 inches square, notched on the guide-piles to such a depth as to leave a space between them of a width equal to the thickness of the sheet-piles. If the sheet-piles are to stand more than 8 or 10 feet above the ground, a second pair of wales is required near the level of the ground. The sheet-piles are driven between the wales to about half the depth of the guide-piles, beginning with the sheet-piles next the guide-piles, and working towards the middle of each space between a pair of guide-piles; so that the last or central sheet-pile acts as a wedge to tighten the whole.

In iron sheet-piling the guide-piles may be either tubular[44], or of a form of section[45] like a trough-girder[46] set on end. The sheet-piles are also like trough-girders set on end, being plates stiffened by vertical ribs on the inner side. Their side edges[47] are so formed as to make over-lapping[48] joints, and their lower edges are wedge-shaped.[49]

RANKINE, *Civil Engineering.*

18. PRINCIPLES OF BRIDGE CONSTRUCTION.

NOTWITHSTANDING the variety of forms which may be bestowed upon bridges, with all due regard to scientific designing, correct practical construction and the different principles embodied in each particular example, there are but two which can be considered to bear out the signification of the term in a pure and simple sense. They are the *arch* and the *suspension principle.*[1] All other forms are either combinations or modifications of these in their outward shape or character of internal *strain.*[2] The reason that the arch and suspension principles constitute alone perfect types of bridge construction is owing to the fact that they alone are acted upon by one description of strain, provided always that the conditions of theory are faithfully carried out in practice. There is a close analogy existing between the arch and suspension principles—in the

[42] Leitpfahl. [43] Zange, Zangenhölzer. [44] röhrenförmig. [45] Querschnitt. [46] trogförmiger Träger. [47] Seitenkante. [48] übergreifen. [49] keilförmig.

[1] Das Prinzip des Bogens und des Hängewerkes; *arched bridge* Bogenbrücke, *suspension bridge* Hängebrücke. [2] Spannung.

difference between their relative shapes, or rather position, and in the difference between the nature of the strain exerted upon them under similar circumstances. The form of the one, and the character of the strain produced upon it, are exactly the inverse or opposite of those distinguishing the other, although the amount of each strain is identical. Obviously, for an entire structure, or any of its component parts, to be *strained*[3] throughout by any single description of strain, is the most economical arrangement that can be devised. As the nature of the strain—whether *tensile* or *compressive*[4]—varies with the principle adopted, the selection of one or the other, theoretically considered, will depend upon the limits of the relative resistances to the strains in question of the material of which the bridge is to be built. Practically, there are considerations which do not allow the dictates of theory to be followed universally in these instances. If we imagine an arch bridge to consist of a single *voussoir*[5] or ring and a suspension of a single cord[6] or chain, the subject of form and strain is reduced to its narrowest possible compass. In the comparisons of the strains upon these types of bridges—whatever may be their actual contours[7]—they are assumed not to differ sensibly from an arc of a circle. It might be urged that the arch principle may be simplified by imagining the whole arch to be replaced by a couple of *rafters*[8] or *beams*[9] forming the chord lines of the half arches respectively and meeting at the centre. But a moment's reflection will point out that this substitution violates at once the simplicity of the system. A *transverse strain*[4] is induced on the rafter, in addition to the *thrust*[10] which results from the portion of the arch principle which enters into the design. A practical example of this arrangement is to be seen in the case of a roof of tolerably large span, in which no *ties*[11] or secondary *trusses*[12], for some reason or other, can be introduced. Each rafter is thus a beam or *girder*[13] sufficiently deep and strong to carry its own load. Its *upper* and *lower flanges*[14] will undergo strains of opposite character, and their calculation, and that of those upon the *web*[15], will be determined on the assumption that the design is simply that of an inclined girder.

If we take the analogous arrangement in a suspension bridge, and suppose a couple of tie rods[16] extending from the centre of the span to each tower, the original tensile strain upon the curved chain becomes complicated at once by the inevitable "*sagging*"[17] of the straight ones. Long unsupported tie rods cannot be used in practice any more than unstiffened *struts*[18] of similar dimensions. The range of the former very much exceeds that of the latter,

[3] spannen, in Anspruch nehmen. [4] *tensile strain* Zugspannung, *compressive strain* Druckspannung, *transverse strain* Schubkraft, s. Teil II, Nr. 1 "*Strength of materials*". [5] Wölbbogen. [6] Seil. [7] wirkliche Form. [8] Sparren, Strebe. [9] Balken. [10] Druckkraft. [11] Band, Verbindungsstück, Zugstange. [12] Balken. [13] Träger. [14] Ober- und Untergurt. [15] Rippe, Steg. [16] Zugstange. [17] sich durchbiegen. [18] Strebe.

owing to the different conditions of equilibrium which are produced in them by the action of their respective strains. If a strut be deflected from its normal position in which its longitudinal axis is in a straight line, the strain induced upon it tends to deflect it still further from the position. But if a tie be placed in similar circumstances, the strain upon it will have a tendency to restore it to its original state of *stable equilibrium.*[19] Until ties become of considerable length—as occurs in roof trusses, and in those examples of suspension bridges which are designed with straight rods—there is no necessity for *stiffening*[20] or supporting them. It will be evident, from these considerations, that any attempt, however simple, to alter or modify the strict principle of the arch or suspension type of construction, leads to a direct complication both of parts and strains. The integrity of the two systems is immediately destroyed, a variety of elements being introduced which are completely foreign to the designs, abstractedly regarded.

From these two principles have arisen the numerous combinations that constitute the present practice of bridge-building. All of these differ from the primitive types, in being acted upon by strains of tension and compression, either separately or conjointly. Of the compound forms which embody the principle of the arch in their construction there are two, namely, the *braced arch*[21] and the *bow-string-girder.*[22] The former of these has been used in but a very few instances, although it is, economically, a sound structure, especially for the employment of cast-iron, as the arch itself, and the horizontal or upper member, are both in compression. A distinction must be made between a braced iron arch and an arched rib[22], in which the whole strain is taken by the rib. The new bridge at Blackfriars is an example of the latter type. It is true that the *spandrels*[23] consist of a simple *truss of bars*[24], but they serve merely to transmit the vertical pressure to the rib, and do not act as *bracing*[25] in the sense it is understood to imply when applied to *braced girders* of any description. There is, practically, no strain upon the horizontal member of an arched rib. It is nothing more than a *stringer*[26], and although it is absolutely necessary to the bridge, both as a *stiffener*[27] and to form a support for the roadway, yet the real resistance is supplied by the rib underneath. The heavy spandrels, the stringer, and the quantity of *cross bracing*[28] that must be introduced between each separate rib of a structure similar to that recently erected at Blackfriars, cause a bridge composed of wrought-iron arched ribs to be anything but an economical specimen of engineering. Another instance of the kind is the Victoria

[19] stabiles Gleichgewicht, s. Teil I, Nr. 1. [20] versteifen. [21] Bogenfachwerksträger. [22] Bogensehnenträger; *arched rib* homogener Bogenträger. [23] Bogenzwickel. [24] Füllwerk. [25] Fachwerk; *braced girder* Fachwerksträger. [26] Streckbalken, Streckbaum. [27] aussteifendes Glied. [28] Querverstrebung, Horizontalverstrebung.

Bridge carrying the London, Chatham, and Dover Railway and other lines over the Thames at Pimlico. On the other hand, in the braced arch the horizontal upper member does its own share of duty, and the bracing acts according to the correct signification of the term. It is, in fact, a web just in an ordinary *lattice girder*[29], and undergoes strains of compression or tension, or of both contemporaneously, as the load is partial or uniform, statical or dynamical. The other principal modification of the arch form is the bowstring girder, which is exceedingly well adapted for bridges of large span. In this respect it is quite equal, economically considered, and possibly superior to the horizontal *lattice*[30], although for limited span the latter is preferable. The bowstring is the arch with the substitution of a horizontal *tie*[31] for the lateral resistance of the *abutments*[32], and the addition of bracing between the bow and the tie or string. The theoretical curve for the bow for a mixed load lies between the parabola and the ellipse, but in practice an arc of a circle is the contour adhered to.

The chief reason that renders the bowstring girder an economical form to adopt in large bridges is, that with a uniform load the strains upon the bracing or web are all of a tensile character. It will be suggested here that so long as the *moving* or maximum load[33] is considerable, this is no argument in favour of the system, as the bars in the web must be made strong enough to withstand the maximum compressive strains to which they can be exposed. This is just the point we are coming to, and it is here that the length of the span becomes a part of the question. The effect of any moving load upon a bridge, supposing that effect to consist of two components, weight and *impact*[34], or, in other words, of a statical and dynamical component, is proportional to the ratio existing between the *insistent weight*[35] of the structure itself and the moving load. It is the old story of a man lying down with an anvil on his chest, and another man striking it with a hammer, which of course bore a very small proportion in point of absolute weight to the anvil. By similar reasoning, when the moving load bears a small proportion to the *dead weight*[35] of the bridge, its impactive or dynamical component may be very nearly if not quite neglected, since the moving load per unit of length is a constant, while the weight of the bridge per same unit increases rapidly with an increase in the size of the span; the limit is not far distant when the effect of the impact may be omitted in the calculation. The moving load may thus be considered as a simple addition to the statical load, and the strains calculated accordingly. The bars will be subjected to compressive strains by a partial distribution

[29] Gitterträger. [30] Gitterwerk. [31] Verbindungsstück (Gurt). [32] Widerlager. [33] mobile Last, Verkehrslast = *rolling load*. [34] Stoss. [35] Eigengewicht = *permanent* oder *dead load*.

of the load, but the proportions that have to be given to them by the exigencies of construction will frequently render them more than strong enough to support these without requiring *counter-bracing.*[36] So far as the bracing is concerned, the *uniformly distributed load*[37] acts in direct opposite to the partially distributed moving load, and it is therefore readily perceived that in large bridges the size of the span may be reached, where the tensile strains[4] due to the one completely nullify those of compression due to the other. While the bracing is thus relieved of a great portion of the strain which falls to the lot of its representative in the girder with parallel flanges, it must not be supposed that it is not resisted by some portion of the structure. It really falls upon the bow or upper flange, but from the shape of this member it is an easy and economical task to stiffen it against compressive strains compared with a long diagonal bar.

Returning to the suspension principle, the modifications of it have not been endowed with the success that has attended those of the other primitive type. Innumerable attempts have been made by engineers to construct a suspension bridge[1], simple or compound, which shall be available for railway traffic, but as yet they have all been failures, and in our opinion, always will. We do not mean to assert that it is not possible to build an iron suspension of a very complicated character, which will allow a train to pass over it at the rate of fifty or sixty miles per hour. But we do assert that to do this would cost infinitely more than to erect the bridge upon another and a more secure principle. The difficulty of imparting to a suspension bridge the requisite degree of *rigidity*[38] to permit of the passage of heavy loads at a great velocity, appears insurmountable. We have not space to mention the many different examples of this form, one of the most recent of which is the so-called *cantilever* bridges. These are nothing more than a spurious combination of a semi-suspension bridge and *continuous girder*[39], and are things to be avoided. They include all the disadvantages of both systems without any of their advantages. Many may be inclined to consider that the horizontal girder, or girder with parallel flanges, has a just claim to a title of its own as a primitive type of construction, as it is not derivable in form or theory from either of the two which have just been discussed. In this sense, perhaps, it might; but its liability to strains of a double character[40] debar it from that privilege according to the rules already laid down. In whatever particular shape it may appear, whether as a *tubular*[41], *box*[42], *plate*[43], *Warren*, *lattice*[29], *trellis*[44], or *through* girder, its flanges are both subjected to strains of a different nature,

[36] Gegenfachwerk. [37] gleichförmig verteilte Last. [38] Steifigkeit. [39] kontinuirlicher Träger. [40] entgegengesetzte Art. [41] röhrenförmiger Träger. [42] Kastenträger. [43] Blechträger. [44] Träger mit Netzwerk, engmaschiger Gitterträger.

and its sides or web is placed in a similar position. Of these, the *tubular* may be regarded as obsolete. We shall never build, or at least we ought never to build, another Britannia Bridge. They are costly blunders. The same may be said of the *box* form, which is only the double plate upon a scale so small that it is impossible ever to examine the girder, when it is once riveted up.[45] The "Warren" has exploded for any but limited spans, and would never have enjoyed the share of favour it has, but for the circumstance that it admits of the web being connected to the flanges by pins[46] instead of rivets, and thus offers facilities for erection in localities where skilled labour is scarce and expensive. Regarding the *trellis* in the light of a burlesque upon the scientifically constructed lattice, we find the latter form and the *plate* to be the sole representatives of the horizontal or parallel system. There are no varieties of the plate principle, except that the web may be either double or single. But there are many varieties of the *lattice* girder, in consequence of the different arrangements that may be made with the bracing. Some of these are both unscientific and uneconomical. The web is comparatively the important point in the lattice girder, although the flanges must receive their proper share of skilful treatment as well.

THE ENGINEER.

19. AMERICAN BRIDGES.

THE introduction of iron as a material for constructing bridges was contemporaneous with the rise and spread of our railway system, and to this circumstance must be assigned the reason that timber bridges never attained to any great prominency among us as engineering structures. Spans of magnitude and heavy loads were, comparatively speaking, unknown before the advent of steam locomotion. It was nearly always possible to divert either the under or over route so as to reduce the span to moderate dimensions, and strains[1] arising from the heaviest road traffic were but a trifle to those generated by even the light locomotives of the early railways.

There was also another cause which limited the employment of timber as a constructive material for bridges. It was the prevalency of building in stone, the arch being preferred to any other type of erection. That form was then capable of being much more generally used than now, owing to *headway*[2] not being of such

[45] vernieten. [46] Zapfen, Bolzen.
[1] S. Nr. 18. [2] lichte Höhe.

paramount importance as it is now. In many instances in laying out railways it becomes simply impossible to so adjust the relative levels as to obtain sufficient headway to allow of an arch being turned. Either the horizontal girder[1] must be adopted or the line cannot be made at all. So long as the span was limited this constituted *primâ facie* no valid argument against the employment of *timber bridges*[3], as regards their absolute *strength*[4] and capabilities of carrying locomotive traffic.[10] But there are many other reasons which, especially when aided by those already mentioned, combined to render the use of timber bridges speedily obsolete.

In the first place, the material itself began to fail at home, and although sound wood could be obtained from various foreign parts, it was found impossible to bestow upon it a sufficient amount of durability to warrant its adoption in situations where almost constant repairs could only be effected at serious inconvenience to the passing traffic.

Financially the question turned upon one point, which may be thus stated. After a certain number of years, will the greater first cost of an iron bridge prove less than of a timber bridge together with the sums spent upon its repairs during that period? It is of course assumed during this time that the iron bridge requires no repairs, which, omitting the trifling sum for painting, is true.

Considering that English engineers have virtually discarded timber bridges, the point may be considered as decided against them. The Board of Trade views with great suspicion the proposed erection of any wooden bridges upon a line of railway. Their inspecting officers cannot refuse to pass them so long as their own regulations which permit them remain good, but they are invariably very stringent in the tests they apply to them, previous to allowing the line to be opened to the public. When all these opposing influences are borne in mind, it is not to be wondered at that timber bridges are a thing of the past among English engineers.

The finest examples of timber bridges are to be witnessed on the American railways, and many of them reflect the highest credit upon the engineers of that country. A great deal of ingenuity and mechanical skill has been displayed in the several types of trussed bridges[5] which characterized the first railroads of that vast continent. The reasons at that time, however inconclusive they might be at present, which rendered the adoption universal were based upon grounds the very opposite of those which led to their abandonment here. The material was abundant and frequently on the very spot where it was urgently needed. Granted that the bridge did require considerable repairs at the end of a few years it was cheaper to execute them several times in succession than to build

[3] hölzerne Brücke. [4] Festigkeit, s. Teil II, Nr. 1. [5] Gitterbrücke (Fachwerksbrücke).

them in the first instance of iron, the transport of which to the site would have been attended with enormous expense.

Many of the American timber bridges are now being replaced by iron ones, but timber will for a long time yet continue the chief material for building railway bridges in the United States. The M'Cullum inflexible truss, the Bun, Howe and Long's principles have been all in America, together with so many modifications, improvements and alterations that the inventors would be puzzled to recognize any one particular system among the complicated examples erected. In these trusses there were two distinguishing features which virtually divided them into two respective classes. One of these might be termed the compound and the other the simple system. In the former the whole truss or frame consisted of a combination of the arch and the horizontal principle, a combination which, however accurate and specious in theory, has never worked out well in practice and never will. It is very analogous to the combination of cast-iron girders and wrought-iron tie rods[1], which were used by engineers in the infancy of railways at home, to accomplish a span which the cast-iron girder was unable to effect by its own strength. The theory was that each part, both cast and wrought, would do its own duty and not in any way interfere with that of its neighbour, and that the compression of the cast iron would be exactly balanced by the tension of the wrought. Unfortunately this idea proved delusive, being unmistakably demonstrated by the sudden failure of a compound girder of 90 ft. span, which was attended with fatal results. A few more minor accidents of similar character convinced engineers that the compound girder was defective at any rate in practice, however apparently sound it might be in theory.

The combination of the arch and horizontal systems in trussed timber bridges was not attended with any distinct failure approaching to that just alluded to, but from the fact that it was impossible to secure the accurate performance of each part individually, it soon manifested signs of weakness and distortion.[6] It was soon perceived that there were only two courses to be pursued in order to obtain a firm and substantial structure. The one was to abandon the arch altogether, and resort to the simple horizontal truss, or to design each sufficiently strong to bear the whole load to which the bridge might be subjected. In the latter case the loss of material is palpable.

Tracing the progress of timber bridge building, we find that ultimately the former course was adopted and the arch altogether rejected, thus reducing the case to that of a simple horizontal frame. This type, although it dispenses with the assistance of the

[6] Verwerfung.

subsidiary arch, yet permits the upper member to be either horizontal or curved, as in a bowstring girder.[1]

Passing from timber to iron the late Mr. Roebling's system deserves attention, which promises to have an extensive application in America especially for large spans. His system depends upon what he terms the *parabolic truss*[7], which can be described in a few words. If in an ordinary bowstring girder the chord or string be removed and an inverted arch or bow substituted for it we have the double parabolic form.[8] These two arches or bows being connected by intermediate trussing[9] constitute the parabolic truss. It is assumed that by this system the supporting power, or in other words the strength of the structure is doubled, while the amount of material remains approximately the same. This is doubtful. There is no doubt but that the inverted arch will assist in supporting part of the load, which the horizontal chord will not do, but whether each arch can be designed on the assumption that only half the total load will practically fall to its share is a question not so easy to decide. For small spans there would be little or no advantage gained in the use of the parabolic truss in preference to the ordinary principles of construction, and bearing in mind the greater unsteadiness of its whole figure, its superior economy for large spans, it is a fair subject for discussion.

We have already noticed the combination of the arch and horizontal girder, but there is still another to be mentioned which is adopted in the Niagara Bridge. It is the combination of the arch and cable or suspension principle. Under a uniform load these components will act together with tolerable harmony, but when the structure has to undergo the passage of heavy variable loads, their action is exceedingly uncertain and unsatisfactory.

It would not be difficult to guess what would happen to those compound girders were they subjected to the transit of the Scotch express or Irish mail.[10] We would rather not be in the train. In comparing all bridges in which cables constitute one of the component parts with those on the horizontal principle, and claiming for the former the merit of superior economy, the amount of material contained in the towers is usually overlooked. If this be added to that in the bridge itself the total will more than equal the quantity required in a horizontal girder where towers are not needed.

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[7] Parabelträger. [8] Fisch- oder Linsenträger. [9] Füllglieder. [10] s. Nr. 4.

20. THE NIAGARA SUSPENSION BRIDGES.

The Roebling Niagara suspension railway-bridge has a span of 821 feet; it is suspended by wire cables, and stiffened by timber trussing, containing between the abutments 600 tons of wood and 400 tons of iron. The passage of an ordinary train, estimated to weigh 80 tons, caused a deflection of .41 foot, of which Mr. Barlow computed .182 foot was due to the elongation of the cables.

This bridge has two floors, one 19 feet above the other, leaving a clear space of 15 feet between them. The lower one is used for ordinary purposes, while the upper one is laid with a railway-track and provided with footpaths; the flooring of this is 245 feet above the surface of the water. Two cables support each roadway, making four in all, which are mutually connected, so that the strain of a load is distributed among the whole. These are $10\frac{1}{4}$ inches in diameter, composed of 7 strands of 520 wires each, every wire being calculated to bear a strain of 1,648 lbs., or 12,000 tons in all.

The upper cables are brought, by means of braces, to within a distance of 13 feet from each other at their centers, and the suspenders inclined inward, so as to give a broader base to the structure and assist in assuring its stability.

Instead of a pier at each end, a separate tower is provided for each pair of cables, thus greatly reducing the amount and cost of the masonry.

The upper and lower floors are connected by wooden posts arranged in pairs, and having between them sufficient room for the passage of diagonal truss-rods of wrought-iron 1 inch in diameter, passing from the top of one pair of posts to the bottom of the fourth pair from it, and distributing the pressure, the posts being 5 feet apart, over a space of 20 feet on each side; these have screw threads and nuts on their ends, so as to be capable of being screwed up in case of shrinkage of the timber. There are also a number of diagonal wire stays extending from the top of each tower, and intended to prevent vertical oscillation. Smaller stays attached to the under side of the bridge are anchored to the rocks below.

The new bridge, near to the Niagara Falls, is designed for carriages and foot passengers. On the United States side, the towers are within a few hundred feet of the falls. In length it exceeds the lower bridge 450 feet, being 1,250 feet in the span. The towers are 105 feet high, and are built in pairs $13\frac{1}{2}$ feet apart. Unlike the heavy stone columns of the lower bridge, they are light wooden trestles, 28 feet square at the base and tapering to the top. They are roofed and weatherboarded.

The bridge is sustained by two cables, which were swung in

the winter of 1867—68, when the ice filled the river below the falls. The lower bridge is sustained by four cables, the upper one by two, each of which is composed of seven strands of twisted steel wire, each strand measuring 2 $\frac{3}{4}$ inches in diameter, which together form a cable about 9 inches thick.

The dimensions of the bridge are: The span from rock to rock is 1,190 feet. The span between the centres of the towers is 1,268 feet. The length of the suspended platform is 1,240 feet. Height above the surface of the river, 190 feet. The length of the central portion of the platform resting on cables is 635 feet. The deflection of cables at center causes a rise and fall of the bridge from changes in temperature of 3 feet. The length of the cables between the points of suspension is 1,286 feet; the length of the cables between anchorages is 1,828 feet. Length of cables and anchors, 1,888 feet. Height of towers above rock on Canada side 105 feet, and on American side 100 feet. Base of towers, 28 feet square, and top 4 feet square.

The width of the roadway between the parapets is 10 feet. The bridge is supported by two cables, composed of two wire ropes each, which contain respectively 133 Nr. 9 wires, of 9 pounds to the linear foot; the diameter of the cable is 7 inches. The total weight of the suspended portion of the cables is 82 tons net. The aggregate breaking strain of the cable is 1,680 tons net, and that of the stays 1,320 tons net, making the total supporting strength of the cables and stays 3,000 tons. The number of suspenders is 480, with an aggregate strength of 4,800 tons. The weight of the suspended roadway, including weight of cables and stays, is 250 tons. The ordinary working load is 50 tons, and the maximum load is 100 tons; permanent and transitory load, 350 tons.

KNIGHT'S *American Mechanical Dictionary.*

21. THE GREAT SUSPENSION BRIDGE BETWEEN NEW YORK AND BROOKLYN.—PAY OF OFFICERS, ENGINEERS, AND WORKMEN.

THE East River Bridge has afforded employment to many thousands of workmen since its construction was begun on the day following New Year's in 1870, but of the great number who have come to and gone from the work, four only remain who began to work on the first day. The number of men on the bridge work has varied from 10 to about 900. Recently there were 797 men at work on the bridge, irrespective of the officers of the Board and

the engineer corps. The laborers all work by the hour, and their wages are paid at the end of every two weeks. The whole amount thus far expended for labor on the bridge is $ 1,538,162.53. The amount of the pay roll per week at present is $ 8,325, but a year ago it was about $ 1,000 more. This does not include the pay roll of the engineers, which is $ 3,169.17 a month, or that of the officers of the Board, which amounts to $ 1,231.65 a month.

The list of engineers and their pay per month is as follows: Col. W. A. Roebling, chief engineer, $ 833.33; C. C. Martin, assistant engineer, $ 500; W. H. Paine, $ 333.33; Francis Collingwood, $ 300; George W. McNulty, $ 208.34; S. R. Probasco, $ 250; W. Hildebrand, draughtsman, $ 220.84; W. Vanderbosch, inspector of stone, $ 190; E. F. Farrington, master mechanic, $ 333.33. Total, $ 3,169.17.

The pay of the officers of the company, by the month, is as follows: Henry C. Murphy, president, $ 416,66; John H. Prentice, treasurer, $ 333.33; O. P. Quintard, secretary, $ 333.33; John Garvey, clerk, $ 83.33; A. L. Curtis, clerk, $ 65. Total $ 1,231.65.

The pay of the different laborers by the hour is as follows: Ship carpenters, 30 cents; painters, 22½ cents; riggers, 15 cents; day laborers, 12½ cents; stone masons, 30 cents; helpers, 10 cents; machinists, 25 cents; day watchmen, 12½ cents; night watchmen, 15 cents; blacksmiths, 30 cents and 25 cents; blacksmiths' helpers, 17½ cents and 15 cents; inspector, 35 cents; assistant to inspector, 25 cents; master machinist, 40 cents; steam engineers, 20 to 35 cents; foremen, 25 cents to 40 cents; assistant engineers, 17½ to 20 cents; hod carriers, 17½ cents; carpenters, first class, 25 cents; carpenters, second class, 20 cents; carpenters' helpers, 15 cents to 17½ cents; draughtsmen, 30 to 40 cents; tool dressers, 25 cents; stone cutters, 25 cents; brick masons, 30 cents; stone masons' helpers, 15 to 17½ cents; brick masons' helpers, 15 cents; drivers, 15 cents; general foremen, 40 cents; assistant foremen, from 25 to 35 cents; laborers, 10 to 12½ cents; messengers, 20 cents.

The pay of the bricklayers was recently increased to thirty cents an hour. The pay of the carpenters varies according to their skill, there being now thirty-three employed at thirty cents, thirty-six at twenty-five cents, and ten at twenty cents an hour. The men are employed by the engineers, and there are no recommendations needed beyond skill and physical ability. There is no number of hours fixed for the men, but their work has usually been confined to ten hours a day, although when there is any special feature of the work which is being pushed, the men work twelve hours a day.

In answer to the many inquiries reaching the bridge office, a card has been printed containing the following facts about the structure.

Construction commenced Jan. 2, 1870; size of New York caisson, 172x102 feet; size of Brooklyn caisson, 168x102 feet; timber and iron in caisson, 5,253 cubic yards; concrete in well holes, chambers, &c., 5,669 cubic feet; weight of New York caisson, about 7,000 tons; weight of concrete filling, about 8,000 tons; New York tower contains 46,945 cubic yards masonry; Brooklyn tower contains 38,214 cubic yards masonry; length of river span, 1,595 feet 6 inches; length of each land span, 930 feet—1,860 feet; length of Brooklyn approach, 971 feet; length of New York approach, 1,562 feet 6 inches; total length of bridge, 5,989 feet; width of bridge, 85 feet; number of cables, 4; diameter of each cable, $15\frac{3}{4}$ inches; first wire was run out May 29, 1877; cable making really commenced June 11, 1877; length of each single wire in cables, 3,578 feet 6 inches; ultimate strength of each cable, 12,200 tons; weight of wire, 12 feet per pound; each cable contains 5,296 parallel (not twisted) galvanized steel oil coated wires, closely wrapped to a solid cylinder $15\frac{3}{4}$ inches in diameter; depth of tower foundation below high water, Brooklyn, 45 feet; depth of tower foundation below high water, New York, 78 feet; size of towers at high water line, 140x59 feet; size of towers at roof course, 136x53 feet; total height of towers above high water, 278 feet; clear height of bridge in center of river span above high water, at 90° F., 135 feet; height of floor at towers above high water, 119 feet 3 inches; grade of roadway, $3\frac{1}{4}$ feet in 100 feet; height of towers above roadway, 159 feet; size of anchorages at base, 129x119 feet; size of anchorages at top, 117x104 feet: height of anchorages, 89 feet front, 85 feet rear; weight of each anchor plate, 23 tons; total cost of bridge, exclusive of land, $ 9,000,000. Bridge will probably be completed in 1880. Engineer, Col. W. A. Roebling.

Scientific American Supplement, *Vol. VIII, Nr. 192.*

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22. TUBULAR BRIDGES.

A Tubular Bridge is a bridge formed by a great tube or hollow beam, through the center of which a roadway or railway passes.

A similar principle—that of the truss-beam—had been applied, varying, of course, in details of construction, to timber bridges, both in Switzerland and America; but the idea of the wrought-iron tubular bridge, and the carrying out of the details of construction which made it a success, are due to Fairbairn, to whom is due the credit of devising the form and proportions of the tubular bridges

of Conway and Menai. The rectangular cellular beam laid on its edge and constructed of wrought and cast iron in their respective places was Fairbairn's, as was also the idea of making it self-supporting. Stephenson very reluctantly gave up the idea of supporting it by chains.

The most remarkable one ever constructed is that across the Menai Straits, on the Chester and Holyhead line of railway, and which unites the island of Anglesea with the mainland of Wales.

Several requirements were made in regard to the tubular bridge to be erected over the strait.

Trains of all kinds were to cross it at full speed.

The Lords of the Admiralty stipulated that it should not be less than 105 feet above high-water level.

And that neither scaffolding nor centering should be used, as they would temporarily impede navigation at all points.

Stephenson, at first, designed a cast-iron bridge of two arches, in which the necessity for centering was obviated by connecting together the half-arches on each side of the center pier, on the principle suggested by Brunel. The two half-arches would thereby counterbalance each other, and be prolonged until they met their counterparts, which would spring from the abutments on each side of the straits.

This plan was rejected by the Admiralty, as it gave the specified height at the *crowns* only of the arches.

The idea of the *beam* was then conceived, and the question arose how to build it. The round, or elliptical, form naturally presented itself, and, after the spans were determined, the three towers were commenced, and an expert board was appointed to determine the shape and structure. The board consisted of Messrs. Fairbairn, Hodgkinson, and Clark.

The points determined were,—

The tube must resist compression on its upper portion and extension on its lower portion.

The material should be principally accumulated above and below, and the middle should be hollow, whether it was of iron or wood.

Several evident reasons indicated iron as the material, and it was eventually determined to run the trains *through* the hollow iron beam instead of *upon* it.

Experiments determined that, while a cylindrical tube, with a given weight, was rent asunder beneath, and an elliptical tube was crushed at the top, a rectangular tube was more rigid than either.

Then followed the discovery that, instead of riveting together layers of plates, the same amount of material in a cellular form would give greater strength; so the layers were divided, and the

spaces between them subdivided, by upright plates, into cells extending throughout the top and bottom of the tube.

The plate-iron sides and angle irons formed ribs and skin to the double spine.

Chains for assistant support were contemplated, but eventually discarded. The tube was calculated to bear a distributed weight of 4,000 tons (2,240 pounds each), or 2,000 tons in the center; being 9 times the calculated load it would have to bear.

The piers are 3 in number, and the land abutments 2; the tubes 4, in appearance (or rather they appear continuous), but they were made in pairs, one for *up trains*, the other for *down trains*, so that there are actually 8 tubes, forming parallel bridges of 4 tubes each. The tubes next to the shore, on each side, were built upon scaffolding, and are each 230 feet long. The two spans in the middle of the strait are each 472 feet in length, and rest upon 3 towers or piers; the outer ones have each a base of 55 feet $\times$ 32 feet, and are 198 feet high. Each contains 210 tons of cast-iron beams and girders.

The central, or "Britannia", pier is 460 feet distant from its fellows, and is founded upon a rock. It is 230 feet high, and has a base 62 $\times$ 52 feet. It weighs 20,000 tons (English). Its exterior has 148,625 cubic feet of granite, filled in with 144,625 cubic feet of sandstone. 387 tons of cast iron beams, or girders, are worked into it.

The tubes are composed of wrought-iron plates, from $\frac{3}{8}$ to $\frac{3}{4}$ of an inch thick, the largest being about 12 feet in length, strongly united by rivets, and stiffened by angle-irons, and vary in exterior height, which is 30 feet at the center of the bridge, diminishing to 22 feet 9 inches at the abutments. Their exterior width is 14 feet 8 inches, or 13 feet 8 inches in the clear, inside.

The tubes were built upon platforms on the Caernarvon shore, and floated on pontons into spaces between the piers. One side of a tube was floated into a vertical recess in one side of the tower formed for its reception, and then the other was floated down into a similar recess in the other tower, a portion of the lower masonry being omitted to allow it to pass in. These vertical recesses in the sides of the tower formed guides for the ends of the tubes while being raised to their elevated position. 800 men were employed in the removal of a tube, which was deposited on ledges of masonry on the piers.

The raising of each tube was separately performed by means of powerful hydraulic presses. The larger press had a cylinder 11 inches thick, the piston 20 inches in diameter, and a lift of 6 feet. The cylinder weighed 16 tons, the machine 40 tons (English, 2,240 pounds).

Two smaller presses had rams 18 inches in diameter, and acted

at one of the tubes, while the larger one operated at the other end. They stood on the piers, and lifted by chains. The chains and lifting-frames added 400 tons to the weight to be lifted.

The power was derived from 2 steam-engines of 40 horse-power each, delivering water through a $\frac{1}{2}$-inch pipe into the cylinder below the ram. As the tube rose it was secured beneath. It was raised by successive lifts of 6 feet each, each occupying 30 minutes. The ends rest on rollers so as to allow the tube to expand and contract without grinding the coping of the pier.

The bridge contains 9,480 tons of wrought-iron, 1,988 tons of cast-iron, and 1,500,000 cubic feet of masonry. Its cost was about $ 3,000,000. It was first crossed by a railway train, March 1, 1850.

The Victoria tubular bridge at Montreal, forming a part of the Grand Trunk Railway of Canada, was designed by Stephenson, and built under his direction by James Hodges of Montreal. It was completed in December, 1859, and opened for travel August 25, 1860.

The total length of this immense structure is only 176 feet less than two miles; it is supported upon two abutments and 24 piers, having 25 spans of tubing, the center one of which is 330, and each of the others 242 feet long. The height of the central tube is 60 feet above the summer level of the water. The bridge has a slight descent from the center toward each end. The two center piers are 24 feet wide, the others being 16 feet, and each presents a wedge-shaped cutwater up stream to break the ice, which on the St. Lawrence frequently attains a thickness of 3 to 5 feet, often becoming piled to the hight of 50 feet or more on breaking up in the spring. The tubing of this bridge differs principally from that of the Britannia Bridge, before described, in not being cellular at top and bottom. Each plate and piece of iron was punched in England before being sent to Canada, so that little, except putting them together and placing them in position, remained to be done on the spot. This, however, was a work of great labour, requiring the erection of a rigid timber stage or trussing supported by massive temporary piers of wood, on which the tubes were built up plate by plate. These trusses were removed when the work was completed, leaving the tubes resting at each end on the piers and abutments alone. Expansion and contraction are provided for by rollers underneath the end of each span. The total cost was £ 1,250,000. The first stone of this bridge was laid July 22, 1854; and on December 17, 1859, the first train passed over.

KNIGHT'S *American Mechanical Dictionary.*

23. MR. LAW'S REPORT ON THE TAY BRIDGE.*

45 and 46, Queen Anne's-Gate, Westminster,
9th April, 1880.

To the Commissioners for the Tay Bridge Casualty.

Gentlemen,

In obedience to the instructions contained in your communication of the 22nd of January, 1880, I have now the honour to lay before you the following Report, embodying the information which I have been able to obtain upon those matters which have a bearing upon the casualty which occurred to the Tay Bridge on the night of the 28th of December, 1879.

In accordance with your subsequent instructions, in the present Report I have confined my attention exclusively to that portion of the bridge which has fallen; and for the sake of brevity and distinctness, I have omitted all reference to those details and particulars of the structure, which, although they may have an important bearing upon the question of reconstruction, have no connection with the cause of the catastrophe.

The bridge, as constructed, consisted of 85 *spans*[1], namely, 28 still standing upon the southern side of the river, varying in span from 67 ft. to 145 ft., 13 spans which have fallen, and 44 still standing on the northern side of the river, and varying in span from 162 ft. 10 in. to 28 ft. 11 in.

It will not be necessary to refer to the construction of any other portion of the standing parts of the bridge beyond the two spans immediately contiguous to those which have fallen.

These consist of *wrought iron lattice girders*[2] resting upon *piers*[3], each of which is composed of six *cast iron columns*[4], *braced*[5] with wrought iron *struts*[6] and *ties*[7], resting upon *foundation piers*[8] of *masonry*[9], *brickwork*[10], and *concrete.*[11] The southern span is 145 ft., and the northern span is 162 ft. 10 in. Each girder is 16 ft. 6 in. in height, and their distance apart, from centre to centre, varies from 9 ft. at their *in shore-ends*[12] to 14 ft. 10 in. at the ends adjacent to the fallen spans.

These girders rest upon seven cast iron *rollers*[13], bearing upon raised surfaces on thick cast iron *bearing plates*[14], the rollers having *bevelled flanges*[15] to serve as *guides*[16], but there being no attach-

[1] Spannweite, Brückenweite. [2] schmiedeeiserne Gitterträger. [3] Pfeiler. [4] gusseiserne Säule. [5] verspreizen, verbinden. [6] Strebe, Spreize. [7] Verbindungsstab, Spannstange. [8] Grundpfeiler. [9] Quadersteinmauerwerk. [10] Backsteinmauerwerk. [11] Konkret, Beton. [12] Enden nach den Ufern zu. [13] Lager, Rolle. [14] Unterlagsplatte, Grundplatte. [15] facettirte, zugeschärfte Flantschen. [16] Führung.

* Mr. Henry Law, M.I.C.E., was employed by Mr. Rothery, Mr. Barlow, and Col. Yolland to examine the Tay Bridge after the fall of a portion of it, and to prepare a report thereon. This report constituted an important portion of the evidence adduced during the trial.

ment between the girders and the piers. The ends of these girders are *strengthened*[17] to enable them to carry the ends of the larger girders which have fallen, forming a table or shelf upon which the latter girders rested, three cast iron rollers being interposed to allow the girders to expand or contract. These rollers were provided with flanges similar to those below, but there was no attachment between the upper and lower girders. The *upright ends*[18] of the lower girders were *steadied*[19] by two *transverse wrought iron girders*[20], one at the top and the other at the bottom, with diagonal *tee iron stays.*[21]

In the portion of the bridge yet standing, the rails are carried upon *transverse timber beams*[22] laid upon the upper surface of the girders, but in the portion which has fallen the rails were carried upon transverse wrought iron beams, resting upon and secured to the *lower booms*[23] of the girders.

The length of the portion of the bridge which has fallen is 3149 ft., consisting of three separate girders, the southernmost one being 1225 ft. in length, divided into five equal spans, each of 245 ft., the middle girder being 944 ft. in length, divided into four spans, of which the two outer ones are each 227 ft., and the two inner ones each 245 ft., and the northernmost girder, which is divided into four equal spans, each of 245 ft. It will thus be seen that the fallen portion of the bridge consisted of eleven spans, each of 245 ft., and two spans, each of 227 ft.

The *gradient*[24] of the railway over the southern standing portion of the bridge is a rising one of 1 in 35·368, and this gradient was continued over the first span. Over the second span the gradient changed to 1 in 490, still rising; the line then continued *level*[26] for six spans, this being the most elevated portion of the bridge; the next span had a *falling gradient*[27] of 1 in 130, and the remaining four spans had a falling gradient of 1 in 73·56, which continues over nearly the whole of the northern portion of the bridge.

The course of the railway over the fallen portion of the bridge, and for a considerable distance upon each side of it was a continuous straight line.

The fallen portion of the bridge consisted of wrought iron lattice girders 27 ft. in height, placed at a distance of 14 ft. 10 in. apart[28] from centre to centre. The upper and lower booms were trough shaped[29], being each 2 ft. in width, and between 15 in. and 16 in. in depth. The girder over each span was complete within itself, the *vertical ends*[30] being of similar section to the booms,

[17] verstärken. [18] die geraden Enden, Abschlussständer. [19] befestigen, versteifen, verstärken. [20] schmiedeeiserner Querträger. [21] eiserne T-förmige Spreizen, Verstrebungen. [22] hölzerne Querschwelle. [23] Untergurt. [24] Neigung. [26] horizontal. [27] Gefälle. [28] seitlich. [29] trogförmig. [30] verticale Endständer.

only 18 in. in width upon the *face*[31]; the lattice bars, which had only a tensile strain to resist, consisted of *flat bars in pairs*[32], one being *rivetted*[33] to each side of the booms; those which were in compression consisted of I-shaped struts placed between the sides of the booms, and secured to them and to the *tensile bars*[34] at their intersections.

The upper booms were braced by transverse wrought iron beams with diagonal stays. The railway was carried upon *transverse* wrought iron *fish-bellied girders*[35] about 5 ft. 5 in. apart, which rested upon the upper side of the lower booms, and being rivetted thereto served as struts to the girders, the bracing being rendered complete by diagonal angle iron stays, crossing through the centre of each alternate transverse girder. In order to lessen the transverse strain upon the *bottom boom*[36], suspension bars of wrought iron were attached to the lattice bars at their intersections, and rivetted at their lower extremities to the sides of the boom.

The various parts of these girders have been carefully proportioned to the several strains to which they had to be exposed, and as the catastrophe did not result from the failure of these girders, it is not necessary more particularly to describe them. It is, however, desirable to make an observation with reference to how far each division should be regarded as having formed a *continuous girder*.[37] As already mentioned, each girder was complete in itself, and the booms of these separate girders were connected by *cover plates*[38] with the intention of making them continuous; but in the face of the evidence given at Dundee, of the manner in which these connections between the girders were made, I do not think that these divisions can be considered to have been continuous in such a manner as to produce an increased pressure upon any of the piers. It was stated by William Oram—Question 6494—that the connecting cover plates were temporarily secured by *service-bolts*[39], which were afterwards removed and replaced by rivets; the bridge in the meantime being used for the passage of heavy ballast trains—Questions 6821 to 6825. It is true that the ends of the girders had been originally raised before the cover plates were bolted on; but it must be evident that no strain such as would produce continuity in the girders in the sense now under consideration could have existed, for if it had it would have been quite impossible to have removed any of the bolts.

Judging from the portion of the bridge which is standing, the permanent way appears to have been very carefully constructed. The rails are laid upon *longitudinal timbers* or *way-beams*[40], 18 in. wide by 15 in. in depth, the rails themselves are of steel, 75 lb.

[31] Aussenseite. [32] doppelte Flacheisenstäbe. [33] vernieten, aunieten. [34] Zugstange. [35] fischbauchförmiger Querträger. [36] Untergurt. [37] kontinuirlicher Träger. [38] Deckplatte. [39] Dienstbolzen, interimistische Bolzen. [40] hölzerne Längsschwellen.

to the yard, with *guard rails*[41] of the same weight and material, both rails being secured in the same *chairs*[42], which are placed 3 ft. apart; a flat wrought iron tie bar is also introduced at distances of about 19 ft. apart, to preserve the line in *gauge.*[43]

The *platform*[44] of the bridge was formed of *planks*[45] 4 in. in thickness, covered with asphalte and with a few inches of *ballast*[46] as a preservative against fire.

I now proceed to describe the most important part of the structure in connection with the subject under consideration, namely, the piers upon which the fallen portion of the bridge was supported.

No. of pier.	Height of pier.	No. of span.	Width of span.	Description of bearing on pier.
	ft. in.			
28	67 6	29	245	3 rollers on lower girders.
29	82 6	30	245	8 rollers on pier.
30	83 0	31	245	8 rollers on pier.
31	83 0	32	245	Bolted to top of pier.
32	83 0	33	245	8 rollers on pier.
33	83 0	34	227	6 rollers and an expansion joint.[51]
34	83 0	35	245	8 rollers on pier.
35	83 0	36	245	Bolted to top of pier.
36	83 0	37	227	8 rollers on pier.
37	82 8	38	245	6 rollers and an expansion joint.
38	82 4	39	245	8 rollers on pier.
39	82 0	40	245	Bolted to pier.
40	81 8	41	245	8 rollers on pier.
41	66 10	—	—	3 rollers on lower girders.

These piers each consisted of an assemblage of six cast iron columns, braced by means of wrought iron *studs*[46a] and ties. Their foundations consisted of hexagonal-shaped piers of concrete, *faced*[47] with brickwork, measuring 27 ft. 6 in. in length from point to point of the *cutwaters*[48], and 15 ft. 6 in. in width. These piers were carried to a height of 5 ft. above the level of high-water of spring tides, the upper four *courses*[49] being faced with stone, and no movement or *settlement*[50] appears to have taken place in them.

The height from the top of the upper course of the masonry to the under side of the lattice girders varies from 83 ft. to 81 ft. 8 in; in the following description, and in all the calculations the

[41] Schutzschiene, Sicherheitsschiene. [42] Stuhl, Schienenstuhl. [43] Spurweite. [44] Brückenbahn. [45] Bohlen. [46] Bettungsmaterial, Beschotterung. [46a] *stud* Strebe. [47] verblenden. [48] Pfeilerkopf, Pfeilerspitze. [49] Schicht. [50] Senkung, Sackung. [51] Expansions- oder Dilatationsvorrichtung.

highest pier is referred to; as, however, the height of the pier affected the strength, it may be desirable to give in a tabular form the heights of the several piers above the masonry and the spans of the girders which they supported; the numbers in the first column are the numbers of the piers in the structure, counting from the southern side, and, to avoid confusion, will be adhered to throughout this Report.

Cast iron base pieces, 2 ft. in height, for the reception of the columns, were secured to the piers, each piece having four holding-down bolts passing through the upper two courses of masonry, each of which was 15 in. in thickness.

The six columns were arranged so as to form two clusters [52], each triangular on plan, and having no other connection at their upper extremities beyond the struts and ties. The two extreme columns, 1 and 4, were each 18 in. in diameter, and inclined inwards at the top 12 in. in their whole height; the other four columns, 2, 6, and 3, 5, were each 15 in. in diameter. They stood in vertical planes parallel to the direction of the bridge, but in those planes 2 and 6 and 3 and 5 were each inclined 12 in. towards each other in their whole height.

Each column was composed of six flanged pipes, connected at their *joints* [53] with eight *screwed bolts* [54], each $1\frac{1}{8}$ in. in diameter. Each triangular cluster was surmounted [55] by a wrought iron box girder L-shaped on plan, taking its *bearings* [56] upon the three columns; and upon this box girder another wrought iron *cellular girder* [56a] was placed, running in the direction of the axis of the bridge, and vertically under the longitudinal lattice girder of the bridge itself. Upon the upper side of this cellular girder was bolted a massive cast iron plate, a similar plate being also bolted to the underside of the longitudinal lattice girders of the bridge, and between these two plates were placed the cast iron rollers, each 5 in. in diameter and 2 ft. in length, upon which the weight of the bridge was carried. This description applies to all the piers, excepting Nos. 31, 35, and 39, in the case of which piers the rollers were omitted, and the longitudinal lattice girders were united to the cellular girders by screwed bolts.

Measuring across the bridge, the cellular girders were equally distant from the centres of the tops of columns 1, 2 and 6, and 3, 4 and 5, and consequently the pressure of the girders of the bridge was borne half by each outer 18 in. column, and one-fourth by each inner 15 in. column.

The three columns forming each triangular group were braced to each other at every joint by wrought iron struts and ties; the

[52] Bündel, Gruppe; *on plan* im Grundriss. [53] Stoss. [54] Schraubenbolzen. [55] überbauen. [56] Stützung, Unterlage. [56a] Zellenträger.

struts were horizontal and consisted of two *channel irons*[57] placed back to back and bolted at each end by two $1\frac{1}{8}$ in. bolts to *lugs*[58] cast upon the columns. Each of the rectangular openings formed by the columns and struts was stayed diagonally by flat wrought iron bars $4\frac{1}{2}$ in. broad and $\frac{1}{2}$ in. in thickness, the upper ends being connected with the columns by $1\frac{1}{8}$ in. bolts passing through lugs cast upon them, and the lower ends being secured to two *sling plates*[59], each $4\frac{1}{2}$ in. by $\frac{3}{8}$ in. thick, by *gibs and cotters*[60], and the sling plates being connected with the columns by $1\frac{1}{8}$ in. bolts passing through lugs cast on to them.

The two triangular clusters of columns were braced to each other in a similar manner by struts and ties between the 15 in. columns; that is to say, between columns 2 and 3, and columns 5 and 6. Furthermore at each joint a wrought iron rod $1\frac{1}{2}$ in. in diameter was introduced horizontally to tie together columns 2 and 5, and columns 3 and 6.

Having thus given a general description of the portion of the bridge which fell, I proceed to consider the strains to which the several parts were exposed under varying circumstances, and how far the structure was capable of resisting those strains. In order, however, to render this Report as brief as possible, and to avoid as far as can be done the introduction of technicalities, I shall here confine myself to a statement of results, but for your information the mode of arriving at these results is annexed in the form of an appendix.

The four forces to which the structure was liable to be exposed were those resulting from changes of temperature, from the weight of the structure itself, from the weight of a passing train, and from the lateral pressure of the wind.

For our present inquiry the strains produced by changes of temperature may be disregarded, and those resulting from the weight of the structure itself, or when loaded with a train, are very easily ascertained. Assuming for the reasons already stated that no additional strain is produced upon any of the piers in consequence of the continuity of the girders, and assuming a train with the weight and conditions of that which fell with the bridge, namely, having a weight, including the passengers, of 120 tons, and supposing it to be placed over one of the piers in the position which would produce the heaviest pressure, I find that the structure alone would produce a compressive strain upon the 18 in. columns of 1·47 tons, and upon the 15 in. columns of 1·06 tons to the square inch; and that with the train over the pier these strains would be increased to 1·84 tons on the 18 in. columns, and to 1·30 tons on the 15 in. columns.

[57] U-Eisen, C-Eisen. [58] Lappen, Auge, Oehr. [59] laschenartige Platte. [60] Keil und Lösekeil.

There are so many doubtful elements, the values of which have to be assumed in attempting to determine the amount of the strains to which the several parts of the piers would be exposed by the action of a powerful wind pressure, that it is impossible to arrive at any positively definite result.

As regards the actual pressure of the wind upon the structure, I have adopted the same views as those taken by Dr. Pole, and Mr. Stewart, namely, as regards the lattice girders, for the windward girder I have taken the entire area[61] of the outer face, including the way-beams[40] and rails; for the leeward girder I have taken only the surface above the level of the rails[62], and I have supposed that the wind would only exercise half its force against this surface, in consequence of the shelter afforted by the windward girder. As regards the train, I have wholly deducted the surface of the leeward girder which it would shelter, and for the train itself I have only taken half the round surfaces, and have reduced the pressure of the winds by a sixth, that being the extent to which the train would be sheltered by the windward girder.

In the case of the pier I have again adopted the views of Dr. Pole and Mr. Stewart, namely, in supposing that there would be one 18 in. column and three 15 in. columns exposed to the wind, and that the tie-bars and struts would be equivalent to one-fourth of the space—when seen in end elevation—between the columns.

Now, it is a matter of the first importance to determine what wind pressure would suffice to overturn any portion of the train; it is at once evident that the second-class carriage, being the last but one in the train, was the one which had the least stability; and Dr. Pole and Mr. Stewart state that a wind pressure equal to $28\frac{1}{2}$ lb. upon the square foot would suffice to overturn this carriage. They have, however, assumed that the carriage was empty, whereas the evidence of those who collected the tickets shows that there were eight second-class passengers.

In my own calculation I have assumed the average weight of the passengers at 140 lb. each, and I have taken into account the vertical pressure resulting from the action of the wind upon the curved surface of the roof, and the conclusion at which I arrive is that the second-class carriage could not have been overturned with a less wind pressure than 35·68 lb. upon each square foot; and as there is no position in which this carriage could have been placed where it would have been sheltered to a greater extent than between one-seventh and one-eight of its entire surface, it results that the actual pressure of the wind must have exceeded 40 lb. on the square foot to have overturned this particular carriage, in the condition in which it was upon the night of the catastrophe, and

[61] Oberfläche. [62] Schienenoberkante.

without regarding any assistance which the couplings[63] might afford in retaining the carriage upon the rails.

The next subject that I have investigated is the effect which the wind would have in lessening the weight of the superstructure upon the windward rollers, and in increasing the same upon the leeward ones, and the results are shown in the following table:—

	Without any wind.	With pressure of wind equal to			
		10 lb.	20 lb.	30 lb.	40 lb.
	lbs.	lbs.	lbs.	lbs.	lbs.
Without any train:—					
Pressure on west rollers	322,450	300,120	277,930	255,670	233,410
Pressure on east rollers	322,450	344,780	366,970	389,230	411,490
	644,900	644,900	644,900	644,900	644,900
With a train:—					
Pressure on west rollers	427,615	399,205	370,795	342,385	313,975
Pressure on east rollers	427,615	456,695	485,775	514,855	543,935
	855,230	855,900	856,570	857,240	857,910

The slight increase which will be observed in the total pressure upon both rollers with an increased wind is owing to the vertical pressure resulting from the action of the wind on the curved roofs of the carriages.

These pressures upon each set of rollers are, as I have already explained, equally divided between one 18 in. and two 15 in. columns; these pressures are, however, still further modified by the horizontal pressure of the wind acting against the exposed surfaces of the superstructure, pier and train, but to what extent it is very difficult to determine.

If for a moment it is assumed that the pier may, by virtue of the system of bracing, be considered as a rigid structure, and the effect of the bolts in holding down the columns be disregarded, then the wind pressure required to overturn the structure, about the east 18 in. column as a centre, would be 36·38 lb. without any train, and 32·69 lb. on the square foot, with a train over the pier.

But, unfortunately, the piers must have been very far from being rigid structures, in consequence of the imperfect manner in which the struts and ties were connected with the columns. The struts consisted of channel irons, placed back to back with the lug of the column between, and connected therewith by two $1\frac{1}{8}$ in. bolts at each end; the holes for the bolts were cast $1\frac{1}{4}$ in. in diameter,

[63] Kuppelung.

and being rough and larger than the bolts, and the ends of the struts having no *bearing surface*[64] to *abut*[65] against, the struts themselves were only retained in their positions by the pinching[66] action of the bolts. But the security thus afforded must have been very slight, because, owing to inequalities in the surfaces of the lugs themselves, and to the fact that in some cases the holes in the struts had been roughly enlarged with a blunt[67] tool so as to leave a *burr*[68], the actual bearing surface of many of the struts against the lugs was very small.

As regards the flat ties, when the structure was first erected they were tightened up[69] by means of gibs and cotters, but, owing to the *slots*[70] in the bars against which the gibs and cotters bore being rough, and the gibs and cotters also roughly forged, and, further, owing to the holes cast in the lugs not being cylindrical, and to a screwed bolt being used to secure the ends of the ties instead of a pin[71], the real bearing surface was exceedingly small, and a comparatively slight strain would suffice to crush the edge of the hole in the lug into the thread of the screw.[72]

In reference to the tie bars it should also be observed that the bearing surface of the gib against the slot in the bar was quite inadequate, for while the area of the section of the bar exposed to a tensile strain was 1·625 square inches, the bearing surface of the gib being in compression should have had an area of 1·86 square inches, whereas it had only a surface of 0·375 square inches, or about one-fifth of the strength of the bar.

From these circumstances it would result that a lateral pressure against the columns would produce movement in the struts and ties, resulting in the latter becoming slack.[73] And this movement actually did take place, in some of the tie bars still standing I found packing pieces[74] of iron $\frac{1}{4}$ in. in thickness had been introduced between the gibs and cotters, and on inquiry I learned that these had been introduced from time to time since the opening[75] of the bridge.

From the accounts which have been furnished to me it appears that about 150 of these packing pieces were inserted in the ties between the middle of October of 1878 and the time of the bridge falling, and that the necessity for them arose before the bridge had been opened five months. This circumstance clearly shows that there must have been a considerable racking movement[76] in the piers under the united action of passing trains and wind, and I cannot but consider points to the primary cause of the disaster.

[64] Stützfläche, Anstossfläche. [65] stützen, stemmen. [66] einspannen, klemmen. [67] stumpf. [68] Aufwurf. [69] anziehen, anspannen. [70] Keilschlitz, Keilbahn. [71] Stift, Zapfen, Bolzen. [72] Schraubengewinde. [73] schlaff, locker. [74] Packungsstück. [75] Verkehrsübergabe, Eröffnung. [76] Hin- und Herbewegung, schlotternde Bewegung.

For the slackening of these ties and struts means the removal of that condition upon which alone the power of the structure to resist being overthrown by a lateral pressure depends. And it is easy to conceive that a storm of the violent character of that of the 28th of last December would produce such movements, in the connections of these struts and ties with the columns, as would render the columns unable to sustain the additional weight of the train and the lateral pressure of the wind.

An examination of the ruins of pier No. 32, being that over which the train was situated when the structure fell, indicates that the columns doubled[77] up about their joints as the lower lengths of the westward 15 in. columns were pushed over to the west, or in the reverse direction to that in which the rest of the structure fell. A similar action in pushing back the westward columns is seen in piers No. 36, 39, and 40.

The present state of piers No. 29 and 31 affords conclusive proof of a weak point existing in the structure at the time of the overthrow in each of those piers, namely, in pier No. 29 at the level of the top of the second tier of columns, and in pier No. 31 at the top of the lower tier; for the strain at the point of fracture was, in the former case, only five-sevenths, and in the latter case only six-sevenths, of the strain at the base of the pier, while theoretically the strengths of the pier at the base and the points of fracture were the same. It is clear, therefore, that the power of resistance of these two piers had been reduced at the points of fracture in the case of pier No. 29 to the extent of two-sevenths, and in the case of pier No. 31 to the extent of one-seventh of their normal power of resistance.

Considering that the columns are 76 ft. in height, that with a wind pressure of only 20 lb. on the square foot, a pressure of 337 tons will be thrown upon the eastward 18 in. column at the time of the passage of the train, and that a horizontal pressure of $37\frac{1}{2}$ tons is acting against the top of the column, it is easy to conceive what must have been the inevitable consequences of any slackness on the part of the ties.

It is also necessary to point out that owing to the double angle which the ties by which the 18 in. columns are braced make with the direction of the force tending to overthrow the structure, the efficiency of these ties is reduced in the proportion of 1 to 2·73, or to little more than one-third of their full strength, and that any elongation or movement of the ties would allow of nearly three times that movement in a horizontal direction in the point of the column to which they were attached.

There are also other circumstances in connection with the con-

[77] knicken.

struction and workmanship[78] of the bridge which undoubtedly contribute to the catastrophe.

The mode of securing the *holding-down bolts*[79] was not satisfactory, as they had no *anchor-plate*[80] or bearing at their lower extremities, but were merely *inserted*[81] in a hole drilled through the two 15 in. courses of stone, and were then *run round*[82] with cement, and, as the angle of taper[83] of the conical head was only $6\frac{1}{4}$ deg., it is evident that a very slight compression of the cement would allow of a considerable movement in the bolt; some of these bolts have evidently yielded[84] as much as 8 in. in screwing down the *base-piece*[85] at the erection of the bridge, and in one or two cases the stones have been burst by the *wedge*[86] action of the conical head. It would have been better also if they had been carried to a greater depth, so as to have had a greater weight of masonry to be lifted instead of trusting to the adhesion of the cement, which appears to have been very slight, partly in consequence of the smoothness of the sawn face of the stone, and partly, I imagine, from the stone having been dry when set. In many cases the cement has parted from both stones, forming a thin detached sheet of large dimensions. In many cases also the *nuts*[87] at the upper ends of the bolts have a very imperfect bearing upon the base-piece.

Passing on to the columns, it is apparent that many of them have *blow-holes*[88] of considerable size, which have been filled in with a composition of resin[89] and filings[90]; sufficient care does not appear to have been taken to keep the *cores*[91] from shifting, or in properly adjusting the *upper flask*[92], and as a consequence there are many instances of a considerable difference in the thickness of metal on opposite sides of the columns; in some cases the metal on one side being only $\frac{5}{8}$ in., and on the opposite side $1\frac{3}{8}$ in., or a difference of $\frac{3}{4}$ in.; and as is usually the case when the upper side of a casting is thin, the metal becomes *chilled*[93] and has accumulations of scum[94] and air which very much deteriorate from the strength of the metal.

The mode of attaching the ties to the columns by means of lugs was evidently insufficient, as in almost every instance the lugs have been torn away[95], it is difficult to believe that the *burning on*[96] of defective lugs in the manner described by the witnesses examined at Dundee could have been sanctioned by any person who had the intelligence to understand that the whole security of the structure depended upon the strength of these lugs.

I consider that the mode of connecting the columns at the *flange*

[78] Ausführung. [79] Ankerbolzen, Zugbolzen. [80] Ankerplatte. [81] einlassen. [82] vergiessen. [83] Anlauf. [84] nachgeben. [85] Grundplatte, Säulenfuss. [86] Keil. [87] Schraubenmutter, Mutter. [88] Gussblase, Blasenraum. [89] Harz. [90] Feilspäne. [91] Kern. [92] der obere Formkasten, Oberkasten; s. T. I, Nr. 28. [93] starr. [94] Schaum. [95] abreissen. [96] vergiessen, angiessen.

joints[97] was also in some respects defective, the bolts being $\frac{1}{8}$ in. less in diameter than the hole, and the flanges being separated in some cases as much as $\frac{3}{4}$ in., the bolts could not act as steady-pins, and as in several cases there was no spigot[98] on either of the pipes, there was nothing but the pinching of the bolts to prevent the columns from shifting, and there are evidences that some of them did so shift at the time of the catastrophe.

I have not regarded the concrete as having added in any way to the security of the structure, otherwise than in its increasing the weight of the columns and so increasing the moment of stability of the pier; and my reason for taking this view is that the concrete was so unequal in its quality that no dependence could be placed upon its being of proper strength in the place where strength was required.

Before leaving the columns, I should observe that some of the flanges were so imperfectly faced[99] that the only portions of the metal in contact was a strip of about $\frac{5}{8}$ in. round the margin of the flange.

In conclusion, I would sum up by the statement that, in my opinion, the base of the pier was too narrow, occasioning a very great strain upon the struts and ties, that the angles at which the latter were disposed, and the mode of connecting them to the columns, were such as to render them of little or no use, and that the other imperfections which have been pointed out lessened the power of the columns to resist a crushing strain[100]; I consider that the yielding of the struts and ties was the immediate cause of the disaster, but that the other circumstances stated contributed to it.

It is only due to Sir Thomas Bouch, to his assistant, Mr. Thomas Peddie, to Mr. Noble and the officials of the North British Railway, to say that they have afforded me every facility for making the most thorough and searching investigation.

I have the honour to remain, Gentlemen,
Your obedient servant,
HENRY LAW.

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24. ELECTRO-MAGNETIC TELEGRAPH.*

THREE discoveries necessarily preceded the invention of the electro-magnetic telegraph: the properties of the magnet, the

[97] Flantschen beim Stosse. [98] (Röhren-) Hals. [99] abdrehen. [100] s. T. II, Nr. 1.
* S. *Technical Vocabulary*, ch. 23.

modes of developing frictional electricity[1], and voltaic electricity.*

In 1808, Sömmering described a system invented by him, based upon the decomposition[2] of water by the voltaic pile[3], embracing a number of wires equal to that of the alphabet and the numerals, and leading into glass tubes[4] containing water, the bubbles of gas from which, when the electric fluid was conducted[5] into them, served as signals.

Professor Coxe, of Pennsylvania, about the same time suggested telegraphing by means of the decomposition of metallic salts.

Oersted, in 1820, after many years' research into the action of the voltaic current[6] on magnets, announced the fact that the magnetic needle[7] was deflected[8] by such current, exhibiting a tendency to place itself at right angles to the wire[9] through which the current passes; and Faraday discovered in 1821 that the magnet would revolve about the conducting wire[10], or the latter about the magnet.

The experiments of Oersted, farther extended by Ampère, and the discovery by Faraday that magnetism was induced in a bar[11] of soft iron under the influence of a voltaic circuit[12], led the way to the invention of the first really convenient and practical system of electro-telegraphy.

In 1825, Mr. Sturgeon, of London, discovered that a soft iron bar, surrounded by a helix[13] of wire, through which a voltaic current is passed, becomes magnetized, and continues so as long as the current is passing through the wire.

In 1832, Baron Schilling constructed a model of a telegraph which was to give signals by the deflection of a needle to the right or left.

One great practical difficulty was still to be overcome, the resistance of the transmitting wire[10] to the comparatively feeble current engendered by the voltaic battery.

This was conquered by Professor Joseph Henry, now secretary of the Smithsonian Institution at Washington, who, in 1831, invented the form of magnet now generally used for telegraphic purposes, and discovered the principle of "*combination of circuits*, constituting the important invention of *receiving-magnet*, and the *relay* or *local battery*[14], as they are familiarly known in connection with

[1] Reibungselektricität. [2] Zerlegung, Zersetzung. [3] Voltaische Säule. [4] Glasröhre. [5] leiten. [6] Strom. [7] Magnetnadel. [8] ablenken; *deflection* Ablenkung, Ausschlagen. [9] sich rechtwinkelig zum Drahte stellen. [10] Leitungsdraht. [11] Stab. [12] Stromkreis, Schliessungskreis, Kette. [13] Schraubenlinie, Spirale. [14] *local battery* Lokalbatterie, *line (local) current* Linien- (Lokal-) Strom, *local circuit* Lokalkette, *relay* Relais, *Siemens' polarized relay* polarisirtes Relais von Siemens, *permanent magnet* permanenter Magnet, *soft iron core* Kern aus weichem Eisen, *pole* Pol, *tongue* Zunge.

* Ueber Elektricität und Magnetismus sehe man Teil I dieses Werkes, Nr. 10—13, sowie *Technical Vocabulary*, ch. 22—29.

Morse's telegraph. The effect of a combination of circuits is to enable a weak or exhausted current to bring into action and substitute for itself a fresh and powerful one. This is an essential condition to obtaining useful mechanical results from electricity itself where a long circuit of conductors is used."[15]

In 1832, Professor Morse began to devote his attention to the subject of telegraphy; and in that year, while on his passage home from Europe, invented the form of telegraph since so well known as "Morse's."

A short line worked on his plan was set up in 1835, though it was not until June 20, 1840, that he obtained his first patent, and nearly four years elapsed before means could be procured, which were finally granted by the government of the United States, to test its practical working over a line of any length; though he had as early as 1837 endeavoured to induce Congress to appropriate a sum of money sufficient to construct a line between Washington and Baltimore. Professor Morse lived to see his system adopted in its essential features throughout the civilized world.

In the mean while Gauss and Weber, and after them Steinheil, in Germany, were at work, and constructed a short line between the Royal Academy at Munich and the observatory; this, by means of right and left hand deflection-needles, was caused to print[16] dots on a continuous slip of paper, moved by clock-work.[17] While making experiments in connection with this work, Steinheil made the important discovery that the earth might be used as a part of the circuit, thus enabling him to dispense with one half the length of wire which was thought requisite.

The attention of Wheatstone, in England, appears to have been drawn to the subject of telegraphy in 1834.

Morse's first idea was to employ chemical agencies for recording the signals, but he subsequently abandoned this for an apparatus which simply marked on strips of paper[18] the dots[19] and dashes[20] composing his alphabet.[21] The paper itself is now generally dispensed with, at least in this country, and the signals read by sound[22]—a practice which conduces to accuracy in transmission, as the ear is found less liable to mistake the duration and succession of sounds than the eye to read a series of marks on paper.

Bain, in 1846, patented the *electro-chemical telegraph*[23] which dispensed with the relay-magnet at intermediate stations[24]; and subsequently Gintl, in Austria, and Bonelli, constructed telegraphs of this class, varying in details from that of Bain. In Bain's telegraph, a solution of

[15] Citat aus PRESCOTT'S *History of the Electric Telegraph.* [16] *printing telegraph* Drucktelegraph, *writing telegraph* Schreibtelegraph; *key* Taster, *indicator* Schreibapparat, *inkwriter* Farbschreiber. [17] Uhrwerk. [18] Papierstreifen. [19] Punkt. [20] Strich. [21] s. Nr. 25. [22] ein Telegraph dieser Art wird daher "*Sounder*" genannt. [23] elektro-chemischer Telegraph; *prepared paper* präparirtes Papier, *ferro-cyanide of potassium* Ferrocyankalium. [24] Zwischenstation.

ferro-cyanide of potassium in water, to which are added two parts of nitric acid and two of water, is employed. With this long strips of paper are saturated, which being drawn between a metallic roller and stylus operated by means usual in electro-telegraphy,—dispensing, however, with relay-magnets—dots and dashes are produced, as in the Morse system. These appear of a blue color, in consequence of the ferro-cyanide of potassium being converted into cyanide of iron by electric action and contact of the iron stylus with the paper.

Gintl, a German, in his method, also dispenses with the relay, and records messages by the line-current direct. He prepares his paper with a solution of one part iodide potassium and twenty starch-paste in forty parts of water. The iodine being set free colours the starch blue.

Bonelli's telegraph (1860) records a fac-simile of the transmitted message on mechanically prepared paper. The message is set up in type, which are arranged in a box at one side of a carriage that traverses from end to end of a table, and passes back and forth under a bridge placed transversely thereto. The type occupy the lower left-hand side of the carriage, and at the upper right-hand side is placed a strip of the paper. Immediately over the type are five movable teeth, insulated from each other and connected by five wires with a similar number of styles at the receiving apparatus. As the carriage with the types face upwards comes under the bridge, the teeth come lightly in contact with their raised portions, closing the circuit so long as the metallic contact lasts. Thus letter after letter is transmitted. On the right side of the bridge is a writing-comb composed of five teeth made of platinum-iridium alloy, which is not subject to corrosion, insulated from each other and pressing lightly on the paper strip beneath. This would produce, if each tooth were simultaneously traversed by the electric current, five parallel lines on the paper; but as the current only passes to each during the time when some portion of a type is beneath the corresponding tooth of the type-comb at the sending station, they only produce lines at such intervals and of such length as are determined by the form of the type; cavities in the letters and spaces between letters and words being represented by the discontinuation of one or more of the lines. The wagon is moved by a cord and weight, and is secured at one end of the carriage by a hook, which is released by an electro-magnet when a current is sent over the wires. Those at each end of the line are adjusted to traverse their respective carriages in equal or nearly equal times. The paper intended for receiving permanent printing is prepared by being saturated in a solution of nitrate of manganese, which, under the action of the current, leaves a light brown mark. Fugitive printing, as for the press, is done on paper

prepared with iodide of potassium, which affords at first an iodine color, but is liable to fade.

It is said that a speed of 300 in permanent, and of 1200 words in fugitive, printing per minute is attainable by this apparatus.

Wheatstone's first telegraph comprised five pointing needles and as many line wires, requiring the deflection of two of the needles to indicate each letter.

His first dial instrument[25] was patented in 1840; modifications were, however, subsequently made in it. The transmission of messages was effected by a wheel having fifteen teeth[26] and as many inter-spaces, each representing a letter of the alphabet or a numeral, and thirty spokes corresponding to these, and forming a part of the line. The circuit was closed by two diametrically opposite springs, so arranged that when one was in contact with a tooth the other was opposite a space, when the transmitter was turned until opposite a particular letter, and held there, a continuous current being produced, causing an index on the indicating dial at the other end of the line, which had thirty divisions, corresponding to those of the transmitter, to turn until it arrived opposite the letter to be indicated. The revolution of the index was effected by clock-work, the escapement of which was actuated by an electro-magnet at either end of a pivoted beam, the ends of which carried two soft-iron armatures. One of the line wires, as well as one of the contact springs of the transmitter, and one of the electro-magnets of the indicator, was afterwards dispensed with. A magneto-electric apparatus was subsequently substituted for the voltaic battery.

The *single-needle telegraph*[27] of Cook and Wheatstone is caused to indicate the letters and figures by means of the deflections to the right or left of a vertical pointer; for instance, the letter A is indicated by two deflections to the left, N by two deflections to the right, I by three consecutive deflections to the right, and then one to the left, and so on. This is extensively employed in Great Britain and in India.

The same inventors have also contrived a *double-needle telegraph*[27] on the same plan; but this, as it requires two lines of wire, each needle being independent of the other, though greatly increasing the speed with which messages may be transmitted, has not come into general use.

Dr. Siemens, of Berlin, invented an apparatus by which the armatures[28] of the electro-magnets at each end of the line were caused to vibrate synchronously, maintaining the motion of scape-wheels carrying pointers[29] traversing a lettered dial, so that, the

[25] *dial telegraph* Zeigertelegraph; *dial* Scheibe. [26] *toothed wheel* Zahnrad, *tooth space* Zahnlücke, &c., s. Teil II, Nr. 6. [27] *(double) needle telegraph* (Doppel-) Nadeltelegraph. [28] Anker. [29] Zeiger.

vibrations of either armature being checked, the pointers at either end of the line would simultaneously point to the same letter.

Professor Hughes has invented a very ingenious printing-telegraph, depending upon the synchronous revolutions of two or more type-wheels [30] at different stations.

Various forms of dials or pointer telegraphs have been devised by Breguet in France, Siemens and Halske and Kramer in Germany, and various improvements in the details of construction by numerous others which the limits of this article will not permit us even to refer to.

KNIGHT.

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25. THE MORSE ALPHABET.

THE Morse alphabet, consisting of dots and dashes, is universally recognised as a masterpiece of cryptography. The signals, as given below, are arranged in the groups, and accompanied by the mnemonic phrases, adopted by the British Post-office when, in 1870, the transfer of the telegraphs to the government* rendered necessary the rapid training of thousands of telegraphists throughout the kingdom:

[30] Typenrad.

* Der erste öffentliche Telegraphendienst wurde in England 1846 durch die *Electric and International Telegraph Company* eingerichtet. Es bildeten sich bald eine Reihe anderer Gesellschaften (*British and Irish Magnetic Company, United Kingdom Company, London District Company* u. a.), neben welchen auch die Eisenbahngesellschaften Telegraphenbureaux einrichteten. Die Gesetze zur Uebernahme der Telegraphen durch die Regierung (das *Post Office*) datiren von 1868 und 1869. Das *Postal Telegraph Department* begann 1870 mit ungefähr 2900 Telegraphenstationen (einschliesslich circa 1900 Eisenbahnstationen, welche für das *Post-Office* Depeschen annahmen), 1871 betrug die Zahl 3926; 1873 5540; 1878 5311. Die Zahl der Depeschen betrug in den Jahren 1871, 1873 und 1878 resp. 9,850,177; 15,535,780; 22,171,783. Nach dem im September dem Parlament vorgelegten Bericht über das am 31. März endigende Finanzjahr betrug Ende März die Zahl der Telegraphenämter 5331 (einschliesslich 1407 Eisenbahnstationen), die Zahl der Depeschen 26,547,137.

"*The Illustrated London News*" vom 18. September 1880 sagt im Anschluss an den Bericht über das *Post Office*:—"Ten years have elapsed since the telegraphs were transferred to the State, and from the particulars given it appears that whereas the telegraph companies had at the time of the transfer 1992 offices in addition to 496 railway offices, the Post Office can boast of 3924 offices of its own and 1407 railway stations open for telegraph work, or in all 5331 offices, against 2488 under the companies. The number of instruments in use by the companies was 2000; by the Post Office, 8151. In 1869 the total length of submarine cables connecting different parts of the United Kingdom was 139 miles. Last year it was 707 miles. The length of pneumatic tube employed by the companies was 4844 yards; the Post Office now employs 48,260 yards. The total number of telegraphists employed by the companies was 2514 (of whom 479 were women), and the number of messengers 1471. The total number of telegraphists employed by the Post Office last year was 5611 (of whom 1556 were women), and of messengers 4648; but, besides these, many persons are employed in telegraph work who hold no appointment on the establishment, but are paid by the post-masters out of allowance for assistance. Last year the Post Office forwarded 26,547,137 messages, or four times as many as in 1869." (The number of inland letters dealt with in the year was 1,137,997,500; the number of post cards was 114,458,400; the number of book packets and circulars was 213,903,000, and of newspapers 130,518,400. Taking the correspondence of all kinds, the number was 1,586,937,000 showing an average of 46 per head of the population, and an increase of 3.3 per cent. over the previous year).

Group 1.		Group 2.	
·	*E*, Earwigs	—	*T*, Turnips
· ·	*I*, infest	— —	*M*, make
· · ·	*S*, summer	— — —	*O*, oxen
· · · ·	*H*, houses.	— — — —	*Ch*, cheerful.

Group 3.		Group 4.	
· —	*A*, A	— ·	*N*, No
· — —	*W*, wet	— · ·	*D*, difficulty
· — — —	*J*, jacket's	— · · ·	*B*, baffles
· · —	*U*, uncomfortable,	— — ·	*G*, great
· · · —	*V*, very!	— — · ·	*Z*, zeal.

Group 5.		Group 6.	
· — ·	*R*, Remember!	— · —	*K*, Kindness
· — · ·	*L*, law	— · — ·	*C*, conciliates
· — — ·	*P*, preserves	— · — —	*Y*, youth
· · — ·	*F*, freedom.	— · · —	*X*, extremely
		— — · —	*Q*, quickly.

The arrangement for the numerals is equally ingenious. Each figure is represented by five signals, thus:

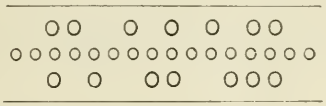
1, · — — — —	4, · · · · —	7, — — · · ·
2, · · — — —	5, · · · · ·	8, — — — — · ·
3, · · · — —	6, — · · · ·	9, — — — — — ·
		10, — — — — —

These are the numerals printed long, but on busy circuits expert clerks adopt the practice of 'sending short', omitting all after the first dash in 1, 2, and 3, four of the dots in 5, and all before the last dash in 7, 8, 9, and 0. It is stated that Prof. Morse founded his alphabet upon information given him by his brother, a journalist, as to the numerical relation of the letters in the English alphabet, the simplest signal (a dot) being given to *E*, and the next simplest (a dash) to *T*, those letters occurring most frequently in our language.

CHAMBERS'S *Encyclopædia.*

26. WHEATSTONE'S AUTOMATIC TRANSMITTER.—THE HARMONIC TELEGRAPH.—THE ELECTRIC PEN.

Wheatstone's Automatic Transmitter.—The speed of the ordinary Morse instrument is limited to the rapidity with which the hand of the operator can move the key, so as to preserve the proper spacing between the marks at the receiving instrument. We are indebted to Sir Charles Wheatstone for an apparatus which trebles, and in some cases quadruples the carrying capacity of a wire, securing, at the same time, mechanical accuracy in the relative size of the dots, dashes, spaces, &c. To effect this, three different instruments are required: First, there is a '*perforator*', by which holes are punched in a paper slip to correspond with the signals required. The operator strikes three discs, the central one producing a central hole, which is of no avail electrically, only carrying forward the paper; the left-hand disc producing two holes, directly opposite to each other, on the sides of this central row; and that on the right producing two holes, placed diagonally to each other. The passage of the electric current is regulated by the position of the outer holes. Those opposite each other admit of a momentary passage of the current through the '*transmitter*'—used in sending the message—while the holes diagonally placed produce a lengthened mark, corresponding to the dash. The following diagram represents the word 'and', as shewn on the punched slip:



As printed at the other end, this reads:

a n d.

The third portion of this instrument is the '*receiver*', in which the currents sent by the action of the punched slips in the transmitter are reproduced in the dots and dashes of the Morse code—the printing being, moreover, done with a mathematical accuracy which keying by hand cannot attain. The speed of transmission depends on the length of line and state of the atmosphere; but the movement of the clock-work, both of transmitter and receiver, is capable of adjustment to any speed below 120 words per minute.

When the Post-office took possession of the telegraphs in this country, the Wheatstone automatic instrument was in use at only

four stations in the kingdom. It has since come into extended use; and one of its most successful applications is in the simultaneous transmission of news from London to a large number of towns. The punched ribbon is carried from one transmitter to the other, the circuit to Birmingham, Manchester, and Liverpool (on which the highest speed is attained) sending it first, and from that instrument it passes to several others, each serving several towns. The adjustment of 'resistance', by which a message is run off simultaneously at Edinburgh, Glasgow, Dundee, and Aberdeen by one sending from London (and so through the various transmitters where this system of 'express news circuits' is adopted), forms one of the most interesting objects of study in the practical working of the telegraph in this kingdom.

Multiplex Telegraphy and 'Phantom' Circuits.—The most original feature of the telegraph section of the Paris Exhibition of 1878, was the *Harmonic Telegraph* of Haskins and Gray, based on principles laid down by Cromwell Varley in 1870. In one application it occupies a place midway between duplex and multiplex telegraphy, namely in the 'way duplex', or as it was felicitously termed by the late Mr. Orton, the 'phantom circuit'. A wire may be occupied by the ordinary business of a series of intermediate offices, while there may be superimposed on that a through traffic (which can be duplexed) between the terminal stations. Thus between Chicago and Dubuque, a wire provides for seventeen intermediate stations, working ordinary Morse sounders, while the harmonic telegraph (the principle of whose action is vibratory currents sent and received by musical forks tuned in unison) works between the terminals. By an extension of this principle we have the multiplex telegraph, each for taking off at the receiving end those vibrations corresponding to its own tone.

The Electric Pen.—Amidst many endeavours to introduce an autographic telegraph, that of Cowper, made public in 1879, is the most successful. It has the drawback of requiring two wires, but is so beautiful in its action as to deserve notice here. Two series of resistances are ranged like the letter L, one series affected by lateral, the other by the up-and-down motion of the sender's pen. At the other end, a *siphon recorder* moves in accordance with the currents thus sent, giving on a moving slip of paper an exact *facsimile* of the writing or other marks of the person sending the message.

CHAMBERS'S *Encyclopædia.*

27. SPECIFICATION FOR TELEGRAPH WIRE.*

The following is a copy of the latest specification issued by the British Postal Telegraph Department for the supply of galvanised iron wire to be employed on their system:—

1. The wire to be uniformly annealed, soft, pliable, smoothly galvanised, free from scale, inequality, flaws, splits and other defects, and must be cylindrical and of one of the sizes shown in the following table, and subject to the hereinafter specified tests.

2. To be drawn in continuous pieces or lengths, of the weights given in the table. Each piece must be warranted not to contain any weld, joint, or splice whatever, either in the rod before it is drawn, or in the finished wire.

3. After having been galvanised, the wire to be passed under and over three or more rollers or pulleys placed at such distances and in such positions as the inspecting officers shall determine, for the purpose of testing the quality of the wire as regards freedom from splits, and to be then stretched ('killed') to the extent of two per cent. by passing round drums, either varying in diameter or differentially geared as to speed. After being stretched, the wire to be smoothly and uniformly coiled, so as to contain no bends or sinuosities.

4. Should any of the wire of No. 8 or No. 11 gauge break during 'killing', the broken coils will be accepted provided:— a) That such broken coils do not exceed five per cent. of the whole. b) That no broken bundle contains any piece of less than 40 lbs. for the No. 8 gauge and 20 lbs. for the No. 11 gauge. c) That the wire is in every other respect in accordance with the specification, and that it passes all subsequent tests.

The makers are not to weld, joint, or otherwise splice any such broken bundles. Should breaks occur in more than five per cent. of the bundles, the whole of the broken bundles will be rejected. Any wire of the No. 4 gauge which may be broken in 'killing' cannot be accepted.

5. Every coil may be gauged for diameter in one or more places.

6. Every coil of the supply may be tested for ductility and tensile strength, and five per cent. of the entire number of coils

* *Telegraph wire* Telegraphendraht, *galvanized iron wire* galvanisirter Eisendraht, *steel wire* Stahldraht, *compound telegraph wire* Stahl-Kupferdraht (mit einem dünnen Kupferstreifen überzogener Stahldraht), *overland* oder *aërial* oberirdisch, *subterranean* oder *underground* unterirdisch, *submarine* unterseeisch, *transatlantic cable* transatlantisches Kabel, *deep-sea cable* Tiefseekabel; *insulator* Isolator, *'Z'-insulator* Doppelglocken-Isolator, *cup* Glocke, *porcelain* Porzellan, *ebonite* Horngummi, Ebonit (*ebonite* is a mixture of two or three parts of sulphur and five parts of caoutchouc baked for several hours at 170° F., under a pressure of four or five atmospheres), *point of support* Stützpunkt, *bracket* eiserne Isolatorstütze, *arm* (hölzerner) Querarm, *binding* Bindung, *joint* Drahtverbindungsstelle, Lötstelle (*to solder* löten); *pole* Stange, *pole-setting* Setzen der Stangen, *earth-borer* Erdbohrer, *stay* Anker, *to stay* verankern, *stay-block* Ankerstein, *strut* Strebe, *to strut* verstreben, *A-pole* Bock, *bolt* Riegel.

may be cut and tested in any part. Coils cut for this purpose or for the electrical tests are not to be welded or jointed together again, but the separate pieces are first to be bound in separate coils and then the two bound together to form a coil of the standard size, so that they may either be conveniently jointed on the work before being paid out, or that broken coils may be chosen for short lengths when required.

7. To prove its ductility the wire must be capable of bearing the number of twists set down in the table without breaking or showing any signs of splitting, or other defect. The test will be made as follows:—The piece of wire will be gripped by two vices and twisted. The twists to be reckoned by means of an ink spiral formed on the wire during torsion. The full number of twists must be distinctly visible between the vices, no fractions being reckoned.

8. Tests for tensile strength are to be made by the direct appliance of weight vertically. No hydraulic machine or lever is to be used.

The wire is at first to lift a weight equal at least to nine-tenths ($\frac{9}{10}$) of the minimum tensile strength entered in the table for the size under trial, and the remaining tenth is to be added gradually by convenient ordinary weights of not less than one-fifth ($\frac{1}{5}$) of the remainder, or one-fiftieth ($\frac{1}{50}$) of the minimum tensile strength. No less weight than one-hundreth ($\frac{1}{100}$) of the minimum will be reckoned.

9. The electrical resistance of the wire is not to exceed the limit shown in the table, and the resistance of each test-piece to be reduced according to its weight, such test-piece being not less than one-thirtieth ($\frac{1}{30}$) part of a statute mile in length. When the weight per mile of any test-piece is either less or more than the required weight, the resistance shall not be so large as that when multiplied into its weight per mile it would exceed the constant number shown in the table, and in all cases where this product is greater than this constant the wire will be rejected.

10. It must be understood that the mechanical and electrical tests referred to in paragraphs 7, 8 and 9 are to be applied to the wire after it has been 'killed', as specified in paragraph 3.

11. The whole of the wire of No. 16 gauge (see table) must be made from what is known as homogeneous metal, or steely iron. Paragraphs 3, 4 and 9 do not apply to wire of this gauge.

12. If, after the examination of any particular parcel of wire, 20 per cent. of such wire does not meet the requirements of all or any of the foregoing stipulations, the whole of such parcel shall be rejected.

13. The approved wire to be made up in coils, properly bound, within the limits of weight shown in the table.

14. Every coil of wire approved to be weighed separately and the weight stamped on a metallic label which is to be firmly affixed to the inner part of the coil.

15. The inspecting officers may be present during the whole process of making the wire, and shall at all times have every facility afforded them by the manufacturers.

16. The testing shall be performed under the control of the inspecting officers, and they may cause to be examined and tested any and every coil, or any part of it. The contractor shall supply all machinery, apparatus, convenience, labour and assistance required for the mechanical testing of the wire, it being distinctly understood that the value of such convenience and service and of the waste incidental thereto is included in the prices stated in the tender.

17. Proper lock-up accommodation must be provided by the contractor for the storage of approved, and for the distinct and safe custody of rejected, wire, under the control of the inspecting officers until finally disposed of on the completion of the contract.

Table referred to in the foregoing Specification.

Nominal size.	Diameter.			Weight per mile.			Minimum breaking weight for standard diameter.	Minimum number of twists in 6 inches.	Maximum resistance per mile of standard weight at 60° F.	Constants: being Standard Weight × Resistance.	Weight of each coil.		Minimum Weight of each Piece of Wire [except as provided for by Clause 4].
	Required (standard).	Minimum.	Maximum.	Required (standard).	Minimum.	Maximum.					Minimum.	Maximum.	
	ins.	ins.	ins.	lbs.	lbs.	lbs.	lbs.		ohms.		lbs.	lbs.	lbs.
4	·24	·235	·245	789	756	822	2200	14	6·5	5128	90	120	90
8	·170	·165	·175	396	373	420	1100	20	13	5148	90	120	90
11	·125	·120	·130	214	197	231	600	27	24	5136	80	112	40
								in 3 inches					
16	·065	·062	·068	57	52	62	. . .	20	. . .	. . .	25	30	5

PREECE & SIVEWRIGHT, *Telegraphy.*

28. COMMERCIAL TELEGRAPHY.

A TEXT BOOK of Telegraphy can scarcely be complete without some explanation of the method adopted in the actual transaction of telegraphic business. The instruments in use have been described, their mode of connection together has been shown, the construction of lines has been illustrated. We have now to assume the existence of an operator at each instrument, and everything prepared for the transmission of messages.*

Message forms.—There are three kinds of messages that the operator has to deal with, and each kind has its own particular form, upon which it is written. The first or *forwarded* message is written on what is known in the British Postal Telegraph Service as the A form; it is printed on *white* paper, and it is the message which is written out and handed in across the counter by the sender himself for transmission by wire. It has to be paid for. The second is the *transmitted* message, which is written on the B form; it is printed on *buff* paper, and is the message received at a telegraph office *by wire* for retransmission *by wire* to some other telegraph office. The third is the *received* message, which is written on the C form; it is printed on *pink* paper, and is a message received by wire at a terminal office for delivery *by hand* to the person to whom it is addressed from that office.

There are other forms used for other classes of messages, which are paid for under special rates, such as *foreign* and *press messages*, or those which are sent *free*, such as messages on the service of the Post Office Department or of a railway company. Every circuit is supplied with pads of these forms, and in order that the clerk who is about to receive a message may know what particular form to use, every message is indicated by a *prefix*, which is the first signal always sent. Thus the letter 'S' shows that a C form must be used; the letter 'X' a B form; 'S G' a service form; 'S P' a press form; 'S A' a free railway message form, and so on. Moreover, these prefixes indicate the order in which these messages must be sent; for some messages, such as those on the business of the State,

* *Telegram.* This word, which was coined some years ago by a writer in the *Times* newspaper, was objected to at the time by Greek scholars as a barbarous formation. According to the law of Greek compounds, *grapho*, compounded with anything but a preposition, becomes *grapheo;* therefore, with *tele*, it would be *telegrapheo*, the noun from which would be telegraphema. The convenient conciseness of *telegram* has, however, made it triumph over the more correct *telegrapheme.* CHAMBERS.—The word *telegram* is of recent American origin, its first occurrence being in the following passage from the Albany Evening Journal for April 6, 1852, emanating from Mr. E. P. Smith, of Rochester: "A friend desires us to notice that he will ask leave, at some convenient time, to introduce a new word into the vocabulary. The object of this proposed innovation is to avoid the necessity, now existing, of using two words, for which there is very frequent occasion, when one will answer. It is *telegram*, instead of *telegraphic dispatch*, or *telegraphic communication. Telegraph* means to write from a distance; *telegram*, the writing itself, executed from a distance. *Monogram*, *logogram*, &c., are words formed upon the same analogy, and in good acceptation. WEBSTER.

or on the urgent business of the Department, take priority over ordinary private messages, as these latter take priority over ordinary Service messages.

Code Time.—But while precedence among the different classes of messages is determined by the prefix, the order of transmission amongst messages of the same class and character must also be determined; otherwise, when several offices are upon the same circuit, considerable confusion would arise if each office could not determine the priority of despatch of its own messages. This is done by the 'code time', which is the signal sent after the prefix. Time is transmitted by code according to the following diagram:—

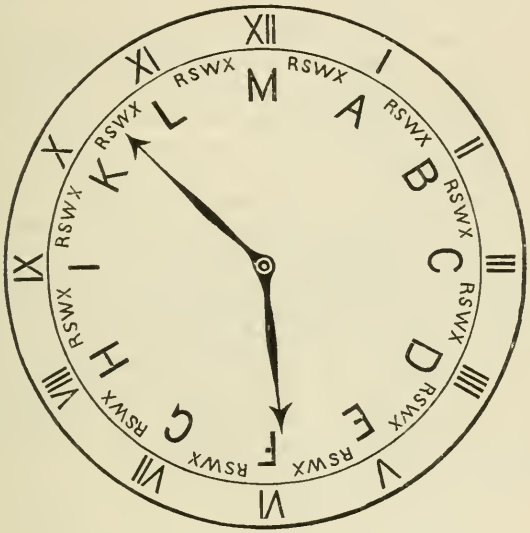


Fig. 6.

The twelve letters from A to M denote the twelve hours. They also denote the twelve periods of five minutes of which each hour is composed. The intervening four minutes are denoted by the letters R S W X. The letters sent *singly* indicate the hours, sent in combination of two they represent the hours and certain periods of five minutes; sent in connection with the intermediate letters R S W X they represent hours and minutes: Thus—

M	is 12	B	is 2	E	is 5
F	„ 6	I	„ 9	K	„ 10
M F	„ 12.30	B I	„ 2.45	E K	„ 5.50
M F S	„ 12.32	B I X	„ 2.49	E K S	„ 5.52

In England, where the despatch of messages is so rapid, and where Greenwich time is uniformly employed, there is no necessity to indicate whether the hour is a. m. or p. m.; but on the continent, where much greater distances and differences of time exist, the distinction is given by M for *matin* and S for *soir*. On the other hand the above codetime system does not exist there, time is sent in full, thus: '12.32 S' or '2.49 M' is signalled as written. The English system is far more concise and rapid.

Station Calls.—Before a message can be sent to any station the attention of that station must be attracted. It must be called, and an answer given to show that the attention of the operator at that station has been secured, and that he is ready to receive a message. In the earlier telegraphs this was done principally by bells, and the bell is still used with the A B C apparatus; but the necessity for bells no longer exists, for each of the other kinds of instruments emits sufficient sound to attract attention. But when several stations are upon the same circuit, how is any one individual station to be selected and attracted? In the same way that in the presence of a company of men when the attention of one, say Brown, is required, 'Brown' is shouted, and Brown replies by a lusty 'here'. So every station is supplied with its name or 'code' to distinguish it from every other station, and when it is wanted it is called by this code and to it it answers. It would be tedious and uncertain to signal the names of stations in full, hence an abbreviated name or *code* has been given to every office by appropriating to it combinations of the letters of the alphabet in groups of two and three. There are 650 combinations of *two* letters of our alphabet, and 15,600 of *three* letters, and as there are only 5,585 postal telegraph offices in England, it is evident that no 'code' consists of more than three letters.

Liverpool	is indicated by	L V
Manchester	"	M R
Bristol	"	B S
Edinburgh	"	E H
Maidstone	"	M A
Hollingbourne	"	H J X
Lenham	"	L D P
Egerton	"	E C N
Charing	"	C E Y
Ashford	"	A D

The last six stations enumerated are all on the same single-needle circuit. Every current sent on that circuit operates each instrument alike and simultaneously. Practically it may be said that they are all in telegraphic sound of each other. Suppose Maidstone has a message for Lenham: he signals on the instrument

'L D P, L D P, L D P.' Every other station hears the call and knows the station wanted, but no one answers but Lenham, whose operator, when he perceives that he is called, replies 'here L D P' or simply 'L D P' only. Ashford having thus secured his attention, signals the prefix and code time and proceeds with the message.

As most sub-offices, like those enumerated above, communicate only with their own head offices, complication is unnecessary, hence, single call letters, viz., D, G, K, O, R, S, &c., for local use have been introduced. The sub-office which comes nearest to its head office is called D, the next in order G, the next K, and so on. Thus the calls on the above circuit would be—

	Code.	Call.
Maidstone . . .	M A	M A
Hollingbourne .	H J X	D
Lenham . . .	L D P	G
Egerton . . .	E C N	K
Charing . . .	C E Y	O
Ashford . . .	A D	A D

Lenham's call would, therefore, be 'G', and he would reply 'G.'

Number of words.—In England the number of words in the *text* of the message only are counted and signalled. This is done solely to secure accuracy in transmission, for every clerk immediately he has received a message counts the number of words in it, and if that agrees with the number signalled, he concludes that his message is correctly received; whereas if the numbers disagree, he at once obtains a correction.

The *instructions* for the delivery of the message after the wire has done its work, together with the office of origin, which formerly were sent at the end of the message, are now signalled after the code time.

Preamble.—These signals, the prefix, the code time, the office of origin, the instructions, and the number of the words, form the *preamble* of the message; and, compared with the preamble in use on the continent, they are very concise. In the continental form of message the preamble consists:—

1. The prefix.
2. Name of station of destination.
3. Name of sending station prefixed by the word *de*.
4. *The consecutive number of the message.
5. Number of words in message.
6. The day of the month.
7. The time to minutes with the indication M or S.

* On the continent every message is numbered consecutively at each office, and any enquiry about that message is referred to that number. In England we speak of a message as 'your A B Jones' by giving the code time, and name of the sender.

8. The station transmitting when it has to be forwarded on by wire.

9. The special instructions for delivery.

All these signals together are equivalent on the average to *ten* words, and are, therefore much more cumbrous than the English form, which, with the special instructions sent at end of the message, do not average more than six words.

The forwarded message.—After the preamble comes the address, and then the body of the message itself. These parts are separated from each other by a distinct signal, called the *break signal* (. . . .), so that the receiving operator knows on what part of the form before him he has to write down the words he reads off.

A complete message with all its entries is shown in the diagram.

The received message.—The clerk who receives the message writes it down in pencil on the proper form which is indicated to him by the prefix. If it is an 'S' message received for delivery to the public an office copy or duplicate is kept. The C forms are made up in pads and in duplicates, thus: the first sheet is the office copy, the next the public form, and so on. The office copy, which is kept for reference, is written with a pencil, contains all the entries of prefix, code time, number of words, &., which the public does not want to know; the rest of the message, which the public does want to know, is transcribed on the public copy by carbonic paper, which is slipped into the proper place between the two forms. Hence, the office copy is in pencil, the public copy in manifold writing. This latter form is folded up, inserted in an envelope, which is addressed and then sent out for delivery by messenger. The entries made on the C form are as follows:—

Prefix *S* Code *EKS*	POST OFFICE TELEGRAPHS.	C.	Words.		Message
Recd. from *T. S.*	Sent at *6 . 20* P M.	Delivery and Charges.	Adds. . .	*11*	
By *T. White*	To *Hinton-by-George* By *M & H*	Means ..... Distance *5/-*	Text . . .	*17*	
MM. Instructions. *M H 5/- paid. Northampton*		Collected. . .	Insts. .	*7*	Dated
		Paid out . . . *5* *0*	Total	*35*	
Handed in at the *Northampton* Office at *5 . 52* P. M., Received here at *6 . 13* P. M.					Stamp.

The transmitted message.—The clerk who receives an 'X' message writes it down in pencil on the proper form, which is indicated to him by the prefix. The prefix, code time, number of

WELSHOVER, ILL.

A

Prefix S

Code E K S

Words.		How Paid.		
Adds.	11	Cash.		.....
Text.	17		6	0
Instns.	7	Stamps...		
Total	35	Total	6	0

POST OFFICE TELEGRAPHS.
(Inland Telegrams.)

Sent at 6.0 P M

To S A By J. Jones

No. of Message For Postage Labels. 252

(Stamps.)

Office Stamp.

MM. Instructions.

Man and Horse 5/-paid Northampton.

FROM

E. D. Teddy

Laura Place

Northampton

Please Write Distinctly.

Addresses Free.

TO

Poulet Earle Esq.

Hinton-by-George

Warminster

1/-	*The*	*Lamb*	*won*	*in*	*a*
	canter	*Master*	*Magrath*	*second*	*Pilgarlick*
	third	*and*	*the*	*Scotchman*	*last*
	as	*usual*			
1/3					
1/6					

9

words, time received, are entered upon it, and the form is then passed on to the next circuit, upon which it is further signalled, and there it is dealt with as a forwarded message. The entries made on the B form are as follows:—

B. POST OFFICE TELEGRAPHS. No. of Message .....

		Words.		MM. Instructions.	Office Stamp.
Prefix *X*	Recd. at *6 . 0* P.M.	*11*	Sent at *6 . 13* P.M.	*M. H. 5/- Paid*	
	From *N H*	*17*	To *S. A.*		
Code *E K S*	By *J. Brown*	*7*	By *F. Smith*	*Northampton*	

Acknowledgment.—Upon the A B C and needle instruments every word is acknowledged as it is received. If a word cannot be read repetition is desired, in the former instrument by giving the letter R, in the latter by giving the letter E. If it be correctly read then it is acknowledged in the former instrument by a complete revolution to *zero*, in the latter instrument by the letter T. Expert operators are very fond of receiving without giving any acknowledgment until the end of the message.

In the Morse and Sounder, when worked by single currents, no acknowledgment is given until the end of the message, unless an evident error is made or the receiver fails to read, when the sender is instantly stopped and requested to repeat.

When numbers are expressed in figures frequent errors are made in their transmission from the great similarity of the signals used. They are, therefore, repeated back, *collated* as it is called, by the receiving clerk as a part of the acknowledgment. But in automatic and duplex circuits the repetition is given by the forwarding clerk at the end of the message. Accuracy is thus ensured.

The acknowledgment on the continent is generally the repetition or *collation* of the numbers or cyphers signalled in the body of the message, and if there be no numbers the repetition of the number of words only.

Modes of Working.—The ordinary mode of working is to send messages consecutively in their order of precedence as indicated by their prefixes and code time, and stringent measures are adopted to prevent any abuse or neglect of code time; but when circuits become crowded with messages, special modes have to be devised to clear off the work. Thus, if we were to take a busy circuit at one extremity of England, say from Plymouth to Penzance, if all the messages forwarded from and received at Penzance were to take their code turn, the forwarded messages would be considerably

delayed by the received messages which arrived with earlier codes from other parts of England, and to which they would have to give way. This is remedied sometimes by adopting what is called *up* and *down* working; that is, by each station sending alternately one or several messages. When only one message is sent from each station alternately it is up and down working proper. When several messages are sent together in one direction it is *batch* working. Five is the favourite number for a batch. Of course each station adheres to code time in its own messages, and each station acknowledges each batch on its completion.

Tablet Check.—It is always desirable to know what amount of work every circuit is doing, and the rate at which this work is being got off. For this purpose every circuit at most of the principal stations is supplied with a form called a *Tablet check*, upon which each message as it goes off is ticked—

Dated Stamp.

POST OFFICE TELEGRAPHS.

Bristol .....

Hours	5 minutes and under	6 to 10	11 to 15	16 to 20	21 to 30	31 to 45	over 45	Total For^{d}.	Re-ceived	Total Rec^{d}.	Total	Remark
9 to 10	,,,,,,,,	,,	,					11	,,,,,, ,,,,	10	21	
10—11	,,,,,,,,, ,,,,,,	,,,	,					20	,,,,,, ,,,,,,	12	32	
11—12	,,,,,,,,,, ,,,,,,,,	,						18	,,,,,, ,,,,,, ,,,,,,	19	37	
12—1												
1—2												
2—3												
3—4												
4—5												
5—6												
Total												

After each message is signalled, the forwarding clerk compares the code time, or time received in the case of a transmitted message, with the time sent, and he makes a tick or stroke upon the tablet form in the column for the delay, corresponding to the number of minutes of difference between these two times. Thus, if the message be received at 11.52 and sent at 11.54, the delay is *two minutes*, and the tick is made in the first column. If the message had not been sent until 11.59 the delay would have been *seven minutes*, and the tick would have been made in the second column, and so on for each column. After each message is received a tick is made in the column for received messages, the delay upon these messages not being indicated. At the end of each hour all the ticks for the forwarded and received messages are added up and inserted in the proper columns, and at the end of the day all the vertical columns are added up and entered in a book or upon a form and filed away for future reference. These forms are summarised upon a return which is sent to the officer in charge of the District every eighth day, who, by taking an average of six or eight of these returns, is thereby acquainted with the amount of work transacted upon every circuit under his charge, and the manner in which this work is got off. He is able thereby to provide for the wants of the service, to see where the shoe pinches, to prevent congestion of the wires, and to supply the circuit accommodation needful for the District.

The essential secret of success in telegraphic working is constant personal supervision, strict and determined discipline, and extreme regularity and tidiness in offices. In England our criterion of good working is this, that each station shall get off 90 per cent. of its work under ten minutes, and 50 per cent. under five minutes. Many stations actually get off 90 per cent. under five minutes. Thus, on August 30, 1875, Brighton, with 1,536 messages, got off 94 per cent. within this period, and most stations exceed the criterion. On August 19, 1875, Bristol, with 4,621 messages, got off 75 per cent. under five minutes, and 97 per cent. under ten minutes.

All messages as they are handed in are paid for in stamps or money; they are recorded in a book called the abstract book, and at the end of the day are collected together, with all those received and transmitted at the station, and sent up with a daily cash account to the General Post Office, where they are examined, checked, and filed away for future reference. All inland messages are kept for three clear months, after which period they are sent to the paper makers to be converted into pulp.

PREECE and SIVEWRIGHT, *Telegraphy*.

APPENDIX.

PATENTS FOR INVENTIONS.

a. INFORMATION FOR INTENDING APPLICANTS FOR LETTERS PATENT FOR INVENTIONS.

Every applicant for Letters Patent must leave at the Patent Office (either personally or by his solicitor [1] or agent) the following documents, the forms for which may be obtained from a law stationer [2]:—

Petition, bearing a 5*l.* stamp;
Declaration;
Provisional specification, describing the nature of the invention (with *drawings*, if necessary to explain the invention); and
Copy of the provisional specification (together with *copies of the drawings*, if there be any).

The sizes of the documents and drawings and the methods of preparing the same are laid down in the Rules and Regulations made by the Commissioners of Patents.

About two or three weeks after leaving the documents the applicant can ascertain if the Law Officer has allowed the invention to be provisionally protected. Every provisional protection is ad-

[1] Unter den Rechtsbeiständen in England sind die *barristers* Juristen in unserem Sinne; sie allein sind berechtigt, das Wort vor den höhern Gerichtshöfen zu führen; mit dem Publikum treten sie in keine direkte Verbindung. Dies fällt den *attorneys* und *solicitors* zu, praktischen Geschäftsleuten, welche den Prozess in Gang bringen und bis zur mündlichen Verhandlung fortführen, auch den *barrister* engagiren und ihm das Beweismaterial liefern; sie sind zugleich Notare, Privatagenten, Vermögensverwalter. — *Attorney General* und *Solicitor General* sind zwei Kronanwälte *(law officers of the Crown)*, Rechtskonsulenten der Regierung, Wortführer in Rechtsangelegenheiten vor dem Unterhause, Vertreter und Anwälte der Krone in Prozessen. (Staatsanwälte in unserm Sinne gibt es in England nicht; Jedermann hat das Recht und die Pflicht, Verbrechen zur Anzeige zu bringen.)

[2] *Law-stationer*, Händler mit den Materialien, welche die *attorneys* und *solicitors* brauchen; sie befassen sich namentlich auch mit Abschreiben von Dokumenten ins Reine gewöhnlich auf Pergament.

vertised in the Commissioners of Patents' Journal; and such protection lasts to the end of the term of six months from the date of the application (*i. e.*, the date of deposit of petition, declaration, &c.).

Instead of leaving a *provisional specification* with the petition and declaration, the applicant may file therewith—

Complete specification, bearing a 5*l.* stamp, and particularly describing and ascertaining the nature of the invention, and in what manner the same is to be performed (with *drawings*, if necessary); and

Copy of such complete specification (together with *copies of the drawings*, if there be any) [see Rules and Regulations].

The invention will then be protected for the term of six months from the date of the application; and every invention so protected is advertised in the Commissioners of Patents' Journal.

The applicant must give notice at the Patent Office of his intention to proceed with his application for Letters Patent (paying at the same time 5*l.*) within four calendar months from and after the date of such application (*i. e.*, the date of deposit of petition, declaration, &c.). This notice of intention to proceed is advertised in the Commissioners of Patents' Journal; and after the expiration of twenty-one days from the date of the Journal in which the advertisement appears the application is referred to the Law Officer, together with the particulars of any objections which may be made by persons interested in opposing the grant of Letters Patent for the invention. If any opposition be made, the applicant on applying to the Law Officer for a hearing of the opposition will have to pay at the Patent Office the sum of 3*l.* 10*s.*, being the fees for the hearing of the case; but this payment is not required when the application is unopposed.

Should the Law Officer decide that the applicant may proceed, application for the warrant of the Law Officer and for the Letters Patent must be made at the Patent Office, accompanied by a payment of 10*l.*, twenty-one days at the least before the expiration of the term of six months from the date of application for the grant of Letters Patent (*i. e.*, the date of deposit of petition, declaration, &c.).

After the sealing of the Letters Patent, and before the expiration of the term of six months from the date of deposit of the petition, declaration, and provisional specification, the patentee must file in this Office—

Specification, bearing a 5*l.* stamp, and particularly describing and ascertaining the nature of the invention and in what manner the same is to be performed (with *drawings*, if necessary); and

Copy of such specification (together with *copies of the drawings*, if there be any) [see Rules and Regulations].

But this *specification* is not required in cases where the applicant has, in the first instance, filed a *complete specification* with the petition, instead of leaving a *provisional specification* therewith.

Before the expiration of the third year from the date of the Letters Patent (*i. e.*, the date of deposit of petition, declaration, &c.) a sum of 50*l.* (stamp duty) must be paid, and before the expiration of the seventh year, a further stamp duty of 100*l.* The patent-right extends without any subsequent payment to the end of the fourteenth year from the date of the Letters Patent.

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b. RULES AND REGULATIONS.

First Set of Rules and Regulations under the Act 15 & 16 Vict. c. 83 [3], for the passing of Letters Patent for Inventions.

By the Right Honourable Edward Burtenshaw Lord St. Leonards Lord High Chancellor of Great Britain, the Right Honourable Sir John Romilly Master of the Rolls [4], Sir Frederic Thesiger Her Majesty's Attorney General, and Sir Fitz-Roy Kelly Her Majesty's Solicitor General, being four of the Commissioners of Patents for Inventions under the said Act.

Whereas a commodious office is forthwith intended to be provided by the Crown as the Great Seal Patent Office; and the Commissioners of Her Majesty's Treasury have, under the powers of the said Act, appointed such office as the office also for the purposes of the said Act.

I. All petitions for the grant of Letters Patent, and all declarations and provisional specifications, shall be left at the said Commissioners' office, and shall be respectively written upon sheets of paper of twelve inches in length by eight inches and a half in breadth, leaving a margin of one inch and a half on each side of

[3] Beim Citiren von Gesetzen betrachtet man alle während einer Parlamentssession erlassenen Gesetze als ein Statut (*Statute Law* das auf einzelnen Reichsbeschlüssen *[acts of Parliament]* beruhende geschriebene Verordnungsrecht, *Common Law* Gewohnheitsrecht), und benennt dasselbe nach dem Regierungsjahre des Königs, oder wenn die Sitzungsperiode von einem Jahre ins andere übergeht, nach beiden; die einzelnen Gesetze bilden einzelne Kapitel dieses Statuts. Also bedeutet "*Act 15 & 16 Vict., c. 83*" das 83ste der in dem 15. und 16. Regierungsjahre der Königin Victoria erlassenen Gesetze. *5 & 6 W. 4. c. 83.* = *Act of the Session of Parliament held in the Fifth and Sixth Years of the Reign of His Majesty King William the Fourth, Chapter Eighty-three.*

[4] *Lord (High) Chancellor*, der Justizminister, Grosssiegelbewahrer und zugleich Vorsitzende des Oberhauses; der zweite in der Rangordnung der Minister (der *First Lord of the Treasury* ist der Premierminister). *Master of the Rolls* Oberarchivar des Reichs und des Kanzleigerichts.

each page, in order that they may be bound in the books to be kept in the said office.*

II. The drawings accompanying provisional specifications shall be made upon a sheet or sheets of parchment, drawing [5] paper, or cloth, each of the size of twelve inches in length by eight inches and a half in breadth, or of the size of twelve inches in breadth by seventeen inches in length, leaving a margin of one inch on every side of each sheet.*

III. Every provisional protection of an invention allowed by the Law-Officer shall be forthwith advertised in the Commissioners of Patents' Journal, and the advertisement shall set forth the name and address of the Petitioner, the title of his invention, and the date of the application.

IV. Every invention protected by reason of the deposit of a complete specification shall be forthwith advertised in the Commissioners of Patents' Journal, and the advertisement shall set forth the name and address of the Petitioner, the title of the invention, the date of the application, and that a complete specification has been deposited.

* All provisional specifications must be written on one side only of each sheet (Feb. 23, 1859).

All specifications in pursuance of the conditions of Letters Patent, and all complete specifications accompanying petitions for the grant of Letters Patent, shall be respectively written bookwise upon a sheet or sheets of parchment, each of the size of twenty-one inches and a half in length by fourteen inches and three fourths of an inch in breadth; the same may be written upon both sides of the sheet, but a margin must be left of one inch and a half on every side of each sheet (Oct. 1, 1852).[6]

The copy of the specification, or complete specification directed by the Act 16 & 17 Vict. c. 115 sec. 3 to be left at the office of the Commissioners on filing the specification or complete specification shall be written upon sheets of brief or foolscap paper briefwise, and upon one side only of each sheet. The extra copy of drawings left with the same must be made on good white smooth-surfaced drawing paper of the same dimensions as the parchment drawing. All the lines of the drawing must be absolutely black, Indian ink of the best quality to be used, and the same strength or colour of the ink maintained throughout the drawing. Any shading must be in lines, clearly and distinctly drawn, and as open as is consistent with the required effect. Section lines should not be too closely drawn. No colour must be used for any purpose upon this drawing. All letters and figures of reference must be bold and distinct. The border line of the drawing to be one fine line only. This drawing must not be folded, but must be delivered at the office of the Commissioners either in a perfectly flat state or rolled upon a roller, so as to be free from creases or breaks. In all cases where the original drawing on parchment is coloured, there must be left, in addition to the above copy, another copy coloured. (Third Set of Rules and Regulations.)

[5] Das Wort "*drawing*" wurde durch Beschluss vom 1. Juli 1871 zugefügt.

[6] Für die begleitenden Zeichnungen wird Grösse von $21\frac{1}{2} \times 14\frac{3}{4}$ oder $29\frac{1}{2} \times 21\frac{1}{2}$ engl. Zoll vorgeschrieben, mit einem Rande von $1\frac{1}{2}$ Zoll.

V. Where a Petitioner applying for Letters Patent after provisional protection, or after deposit of a complete specification, shall give notice in writing at the office of the Commissioners of his intention to proceed with his application for Letters Patent, the same shall forthwith be advertised in the Commissioners of Patents' Journal, and the advertisement shall set forth the name and address of the Petitioner and the title of his invention; and that any persons having an interest in opposing such application are to be at liberty to leave particulars in writing of their objections to the said application at the office of the Commissioners within twenty-one days after the date of the Journal in which such notice is issued.[7]

VI. The Lord Chancellor having appointed the Great Seal Patent Office to be the office of the Court of Chancery, for the filing of specifications, the said Great Seal Patent Office and the office of the Commissioners shall be combined; and the Clerk of the Patents for the time being shall be the Clerk of the Commissioners for the purposes of the Act.

VII. The office shall be open to the public every day, Christmas Day and Good Friday excepted, from ten to four o'clock.

VIII. The charge for office or other copies of documents in the office of the Commissioners shall be at the rate of twopence for every ninety words.

(Signed) St. Leonards, C.
John Romilly, M. R.
Fred. Thesiger, A. G.
Fitzroy Kelly, S. G.

Dated the 1st Oct. 1852.

---

c. FORMS.

No. PETITION.

To the Queen's most Excellent Majesty.

The humble Petition of [*here insert Name and Address of Petitioner*] for, &c.

Showeth,

That Your Petitioner is in possession of an Invention for [*the Title of the Invention,*]

which Invention he believes will be of great public utility; that he is the true and first Inventor thereof; and that the same is not

[7] Diese Fassung der Bestimmungen III, IV und V datirt vom 30. Nov. 1878. Die Ankündigung geschah früher in der *London Gazette.*

in use by any other person or persons, to the best of his knowledge and belief.

Your Petitioner therefore humbly prays, that Your Majesty will be pleased to grant unto him, his executors, administrators, and assigns [8], Your Royal Letters Patent for the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man [*Colonies to be mentioned, if any,*] for the term of Fourteen years, pursuant to the Statutes in that case made and provided.

And Your Petitioner will ever pray, &c.

No. DECLARATION.

I of in the County of do solemnly and sincerely declare, that I am in possession of an Invention for, &c. [*the Title as in Petition,*] which Invention I believe will be of great public utility; that I am the true and first Inventor thereof; and that the same is not in use by any other person or persons, to the best of my knowledge and belief; [*where a complete specification is to be filed with the Petition and Declaration, insert these words*:—"and that the Instrument in writing under my hand and seal, hereunto annexed, particularly describes and ascertains the nature of the said Invention and the manner in which the same is to be performed";] and I make this Declaration conscientiously believing the same to be true, and by virtue of the provisions of an Act made and passed in the Session of Parliament held in the fifth and sixth years of the Reign of His late Majesty King William the Fourth, intituled "An Act to repeal an Act of the present Session of Parliament, "intituled 'An Act for the more effectual Abolition of Oaths and "'Affirmations taken and made in various Departments of the State, "'and to substitute Declarations in lieu thereof, and for the more "'entire Suppression of voluntary and extra-judicial Oaths and "'Affidavits', and to make other Provisions for the Abolition of "unnecessary Oaths". *A. B.*

Declared at this day of
A. D. before me,

A Master in Chancery,
or
Justice of the Peace.

[8] Die Worte "*executors, administrators, and assigns*", abgekürzt *exors, admors, and as*, sind stehende Formel, um alle die Personen zu bezeichnen, die durch einen andern einen Rechtsanspruch haben. *Assign*, gewöhnlich nur in der Mehrzahl und mit *heirs, executors, administrators* verbunden gebraucht, bezeichnet jeden, dem Eigentum übermacht wird. *Executor* ist der Testamentsvollstrecker, der von dem Verstorbenen entweder im Testament oder durch mündlichen Auftrag bestimmt worden ist. Hat der Verstorbene dies unterlassen, oder kein Testament gemacht, so wird ein *administrator* (Vermögensverwalter) ernannt und durch *letter of administration* bevollmächtigt.

No. PROVISIONAL SPECIFICATION.

I do hereby declare the nature of the said Invention for
[*insert Title as in Petition,*]
to be as follows:
[*here insert Description,*]
Dated this day of A. D.

(To be signed by Applicant or his Agent.)

REFERENCE.

(To be endorsed on the Petition.)

Her Majesty is pleased to refer this Petition to to consider what may be properly done therein.

Clerk of the Commissioners.

WARRANT.

In humble obedience to Her Majesty's Command referring to me the Petition of of , to consider what may be properly done therein, I do hereby certify as follows; That the said Petition sets forth that the Petitioner
[*Allegations of the Petition.*]
And the Petitioner most humbly prays,
[*Prayer of the Petition.*]
That in support of the allegations contained in the said Petition the Declaration of the Petitioner has been laid before me, whereby he solemnly declares that
[*Allegations of the Declaration.*]
That there has also been laid before me [a Provisional Specification signed , and also a Certificate ,] *or* [a complete Specification, and a Certificate of the filing thereof,] whereby it appears that the said Invention was provisionally protected [*or* protected] from the day of A. D.
in pursuance of the Statute:
That it appears that the said Application was duly advertised:
Upon consideration of all the matters aforesaid, and as it is entirely at the hazard of the said Petitioner whether the said Invention is new or will have the desired success, and as it may be reasonable for Her Majesty to encourage all Arts and Inventions which may be for the public good, I am of opinion, that Her Majesty may grant Her Royal Letters Patent unto the Petitioner,

his executors, administrators, and assigns [8], for his said Invention within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, [*Colonies to be mentioned, if any,*] for the term of Fourteen years, according to the Statute in that case made and provided, if Her Majesty shall be graciously pleased so to do, to the tenor and effect following:

[*See Form of Letters Patent.*]

Given under my hand, this day of A. D.

(Seal of the Commissioners.)

SPECIFICATION.

To all to whom these Presents shall come;

I of send greeting:

Whereas Her most Excellent Majesty Queen Victoria, by Her Letters Patent bearing date the day of A. D. , in the year of Her Reign, did for Herself, Her heirs and successors, give and grant unto me the said Her special Licence that I the said , my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, [*Colonies to be mentioned, if any,*] an Invention for

[*insert Title as in Letters Patent*]

upon the Condition (amongst others) that I the said by an Instrument in writing under my hand and seal, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in within Calendar Months next and immediately after the date of the said Letters Patent: Now know ye, that I the said do hereby declare the nature of my Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement; (that is to say,)

[*describe the Invention.*]

In witness whereof I the said *A. B.* have heretofore set my Hand and Seal, this day of A. D.

A. B.

LETTERS PATENT.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith; To ALL TO WHOM THESE PRESENTS SHALL COME GREETING:

WHEREAS hath by his Petition humbly represented unto Us that he is in possession of an Invention for which the Petitioner believes will be of great public utility; that he is the true and first Inventor thereof; [that the said Invention has been communicated to him from abroad by;][9] and that the same is not in use by any other person or persons, to the best of his knowledge and belief: The Petitioner therefore most humbly prayed that We would be graciously pleased to grant unto him, his executors, administrators, and assigns, Our Royal Letters Patent for the sole use, benefit, and advantage of his said Invention within our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, [*Colonies to be mentioned, if any,*] for the term of Fourteen years, pursuant to the Statutes in that case made and provided: And We, being willing to give encouragement to all Arts and Inventions which may be for the public good, are graciously pleased to condescend to the Petitioner's request: KNOW YE, THEREFORE, that We of Our especial grace, certain knowledge, and mere motion HAVE given and granted, and by these Presents, for Us, Our heirs and successors, DO give and grant unto the said , his executors, administrators, and assigns, Our especial licence, full power, sole privilege, and authority that he the said , his executors, administrators, and assigns, and every of them, by himself and themselves, or by his and their Deputy or Deputies, Servants or Agents, or such others as he the said , his executors, administrators, or assigns, shall at any time agree with, and no others, from time to time and at all times hereafter during the term of years herein expressed, shall and lawfully may make, use, exercise, and vend his said Invention within Our United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, in such manner as to him the said , his executors, administrators, and assigns, or any of them, shall in his or their discretion seem meet; And that he the said , his executors, administrators, and assigns, shall and lawfully may have and enjoy the whole profit, benefit, commodity, and advantage from time to time coming, growing, accruing, and arising by reason of the said Invention, for and during the

[9] In any application for a Patent which is stated to be a communication, the declaration must state the name and address of the party from whom it has been received in the following manner:—No. 1. When declaration is made in the United Kingdom—"That it has been communicated to me from abroad by (here insert name and address in full)." Nr. 2. In other cases—"That it is a communication from *(A. B.)* a person resident at (here insert address in full)." Febr. 25, 1859.

term of years herein mentioned; TO HAVE, HOLD, EXERCISE, and ENJOY the said licences, powers, privileges, and advantages herein-before granted or mentioned to be granted unto the said , his executors, administrators, and assigns, for and during and unto the full end and term of FOURTEEN YEARS from the day of the date of these Presents next and immediately ensuing, according to the Statute in such case made and provided; And to the end that he the said , his executors, administrators, and assigns, and every of them, may have and enjoy the full benefit and the sole use and exercise of the said Invention, according to Our gracious intention herein-before declared, We do by these Presents, for Us, Our heirs and successors, require and strictly Command all and every person or persons, bodies politic and corporate, and all other Our Subjects whatsoever, of what estate, quality, degree, name, or condition soever they be, within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, that neither they nor any of them, at any time during the continuance of the said term of Fourteen years hereby granted, either directly or indirectly do make, use, or put in practice the said Invention, or any part of the same, so attained unto by the said as aforesaid, nor in anywise counterfeit, imitate, or resemble the same, nor shall make or cause to be made any addition thereunto or substraction from the same, whereby to pretend himself or themselves the Inventor or Inventors, Devisor or Devisors thereof, without the consent, licence, or agreement of the said , his executors, administrators, or assigns, in writing under his or their hands and seals first had and obtained in that behalf, upon such pains and penalties as can or may be justly inflicted on such Offenders for their contempt of this Our Royal Command; And further to be answerable to the said , his executors, administrators, and assigns, according to Law, for his and their Damages thereby occasioned: AND MOREOVER We do by these Presents, for Us, Our heirs and successors, Will and Command all and singular the Justices of the Peace, Mayors, Sheriffs, Bailiffs, Constables, Headboroughs, and all other Officers and Ministers whatsoever of Us, Our heirs and successors, for the time being, that they or any of them do not nor shall at any time during the said term hereby granted in anywise molest, trouble, or hinder the said , his executors, administrators, or assigns, or any of them, or his or their Deputies, Servants, or Agents, in or about the due and lawful use or exercise of the aforesaid Invention, or anything relating thereto: PROVIDED ALWAYS, AND THESE OUR LETTERS PATENT ARE AND SHALL BE UPON THIS CONDITION, that if at any time during the said term hereby granted it shall be made appear to Us, Our heirs or successors, or any six or more of Our or their Privy Council, that this Our Grant is contrary to Law, or pre-

judicial or inconvenient to Our Subjects in general, or that the said Invention is not a new Invention as to the public use and exercise thereof within Our United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, [or that the same was not first introduced therein by the said as aforesaid,] or that the said is not the true and first Inventor thereof within this Realm as aforesaid, these Our Letters Patent shall forthwith cease, determine, and be utterly void to all intents and purposes, anything herein-before contained to the contrary thereof in anywise notwithstanding: PROVIDED ALSO, that these Our Letters Patent, or anything herein contained, shall not extend to be construed to extend to give privilege unto the said , his executors, administrators, or assigns, or any of them, to use or imitate any Invention or Work whatsoever which hath heretofore been found out or invented by any other of Our Subjects whatsoever, and publicly used or exercised within our United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, unto whom Our like Letters Patent, or Privileges have been already granted for the sole use, exercise, and benefit thereof: It being Our Will and Pleasure that the said , his executors, administrators, and assigns, and all and every other person and persons to whom like Letters Patent or Privileges have been already granted as aforesaid, shall distinctly use and practise their several Inventions by them invented and found out, according to the true intent and meaning of the same respective Letters Patent and of these Presents: PROVIDED LIKEWISE NEVERTHELESS, AND THESE OUR LETTERS PATENT ARE UPON THIS EXPRESS CONDITION, that if the said , his executors or administrators, shall not particularly describe and ascertain the nature of his said Invention, and in what manner the same is to be performed, by an Instrument in writing under his or their or one of their hands and seals, and cause the same to be filed in the Great Seal Patent Office within SIX CALENDAR MONTHS next and immediately after the date of these Our Letters Patent: AND ALSO if the said , his executors, administrators, or assigns, shall not pay the Stamp Duty of FIFTY POUNDS and produce these Our Letters Patent stamped with a proper stamp to that amount at the Office of Our Commissioners of Patents for Inventions before the expiration of THREE YEARS from the date of these Our Letters Patent pursuant to the provisions of the Act of the sixteenth year of Our Reign Chapter 5; AND ALSO if the said , his executors, administrators, or assigns, shall not pay the Stamp Duty of ONE HUNDRED POUNDS, and produce these Our Letters Patent stamped with a proper stamp to that amount at the said Office of Our said Commissioners before the expiration of SEVEN YEARS from the date of these Our Letters Patent pursuant also to the said Act; AND ALSO if the said , his executors, ad-

ministrators, or assigns, shall not supply or cause to be supplied for Our Service all such Articles of the said Invention as he or they shall be required to supply by the Officers or Commissioners administering the Department of Our Service for the use of which the same shall be required, in such manner, at such times, and at and upon such reasonable prices and terms as shall be settled for that purpose by the said Officers or Commissioners requiring the same; That then and in any of the said cases these Our Letters Patent, and all liberties and advantages whatever hereby granted, shall utterly cease, determine, and become void, anything herein before contained to the contrary thereof in anywise notwithstanding: Provided that nothing herein contained shall prevent the granting of Licenses in such manner and for such considerations as they may by Law be granted; AND LASTLY We do by these Presents for Us, Our heirs and successors, grant unto the said , his executors, administrators, and assigns, that these Our Letters Patent, or the filing thereof, shall be in and by all things good, firm, valid, sufficient, and effectual in the Law according to the true intent and meaning thereof, and shall be taken, construed, and adjudged in the most favourable and beneficial sense for the best advantage of the said , his executors, administrators, and assigns, as well in all Our Courts of Record as elsewhere, and by all and singular the Officers and Ministers whatsoever of Us, Our heirs and successors, in Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, and amongst all and every the Subjects of Us, Our heirs and successors, whatsoever and wheresoever, Notwithstanding the not full and certain describing the nature and quality of the said Invention, or of the materials thereunto conducing and belonging. IN WITNESS whereof We have caused these Our Letters to be made Patent, this day of One thousand eight hundred and , in the year of Our Reign, and to be sealed as of the said day of One thousand eight hundred and .

BY WARRANT.

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Die in der Physik und Mechanik, in der Chemie und
Maschinen- und Eisenbahnwesen vorkommenden Ausdrücke
sind hier, leicht auffindbar nach den Materien geordnet
gestellt. Der Director der Technischen Hochschule in A
Rath von Kaven bezeichnet diese Vocabularien in eine
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nischen Literatur wie für den mündlichen Verkehr; Hofrath
von Wagner in Würzburg empfahl dieselben angelegentlic
liche Hülfsmittel beim Studium der technischen Literatur,
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